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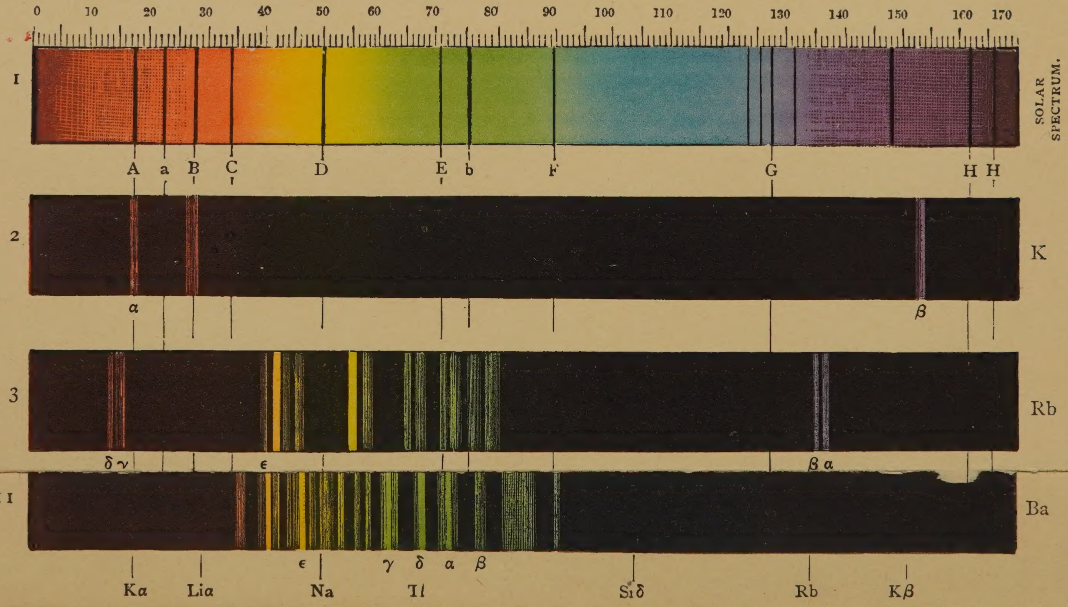
BLOWPIPE ANALYSIS.

Authorized English Edition.

SPECTRA OF THE METALS OF THE ALKALIES & ALKALINE EARTHS.

From the Drawings of Bunsen & Kirchhoff.



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BLOWPIPE ANALYSIS:

BY

J. LANDAUER,

MEMBER OF THE IMPERIAL GERMAN ACADEMY OF NATURALISTS.

Authorized English Edition.

BY

JAMES TAYLOR,

B.SC., WH.SC., A.R.S.M.

SECOND EDITION, REVISED AND ENLARGED.

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PREFACE TO THE SECOND EDITION.

THE favourable reception accorded to this book in the various languages in which it has appeared, could not but satisfy the author as to the soundness of the principles on which the first edition was based. In preparing the present edition, the text has been completely revised, and new methods of approved value have been incorporated, so as to bring the work up to the present time. Some additional details of manipulation will be found of value by readers who are working up the subject without a teacher.

J. LANDAUER.
JAMES TAYLOR.

BRUNSWICK,
SHEFFIELD,
December, 1891.

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EXAMPLES FOR PRACTICE;

Being a collection of Substances well adapted for exhibiting the most important blowpipe reactions.

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1. Antimony.
2. Bismuth.
3. Lead.
4. Tin.
5. Silver.
6. Arsenic.
7. Zinc.
8. Cadmium.

OXIDES.

9. Tin oxide.
10. Zinc oxide.
11. Cadmium oxide.
12. Antimony oxide.
13. Bismuth oxide.
14. Iron oxide.
15. Uranium oxide.
16. Molybdenum trioxide.
17. Chromium oxide.
18. Cobalt monoxide.
19. Copper oxide.
20. Tungsten trioxide.
21. Alumina.
22. Arsenic trioxide.

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23. Sulphides of arsenic and antimony (artificial).
24. Sulphides of arsenic, antimony, lead and copper (artificial).

SALTS.

25. Sodium carbonate.
26. Borax.
27. Microcosmic salt.
28. Hydrogen potassium sulphate.
29. Fluorspar.
30. Potassium chloride.
31. Potassium bromide.
32. Potassium iodide.
33. Sodium chloride.
34. Ammonium chloride.
35. Potassium chlorate.
36. Lead nitrate.
37. Cobalt nitrate.
38. Nickel oxalate.
39. Copper sulphate.
40. Copper chloride.
41. Copper arsenate.
42. Mercurous chloride.
43. Mercuric chloride.

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44. Tin amalgam.
45. Alloy of lead and antimony.
46. Alloy of lead and bismuth.
47. Alloy of lead and zinc.
48. Alloy of lead, copper, and silver.
49. Alloy of tin and copper.
50. Alloy of zinc and cadmium.

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51. Quartz, SiO_2.
52. Gypsum, $CaSO_4 + 2\,H_2O$.
53. Strontianite, $SrCO_3$.
54. Witherite, $BaCO_3$.
55. Magnesite, $MgCO_3$.
56. Muscovite, $3\,Al_2O_3 . SiO_2 + K_2O . 3\,SiO_2$.
57. Orthoclase, $Al_2O_3 . 3\,SiO_2 + K_2O . 3\,SiO_2$.
58. Albite, $Al_2O_3 . 3\,SiO_2 + Na_2O . 3\,SiO_2$.
59. Petalite, $3(LiO . 2\,SiO_2) + 4(Al_2O_3 . 6\,SiO_2)$.
60. Hæmatite, Fe_2O_3.

61. Rutile, TiO_2.
62. Pyrolusite, MnO_2.
63. Lepidolite, $Al_2LiKF_2Si_3O_9$.
64. Apatite, $3(3CaO . P_2O_5) + Ca(F,Cl)_2$.
65. Franklinite, $(FeO, ZnO, MnO), (Fe_2O_3, Mn_2O_3)$.
66. Uraninite, U_3O_4.
67. Chromite, $(FeO, MgO) (Cr_2O_3, Al_2O_3)$.
68. Cerussite, $PbCO_3$.
69. Malachite, $CuCO_3 + CuH_2O_2$.
70. Stibnite, Sb_2S_3.
71. Pyrite, FeS_2.
72. Chalcopyrite, $Cu_2S + Fe_2S_3$.
73. Arsenopyrite, $FeS_2 + FeAs_2$.
74. Smaltite, $(Co, Fe, Ni) As_2$.
75. Cobaltite, $CoS_2 + CoAs_2$.
76. Realgar, AsS.
77. Cinnabar, HgS.
78. Niccolite, NiAs.
79. Molybdenite, MoS_2.
80. Berthierite, $FeS + Sb_2S_3$.
81. Bournonite, $3(Cu_2, Pb)S + Sb_2S_3$.
82. Tetrahedrite. $4(Cu_2, Fe, Zn, Ag, Hg) + (Sb, As, Bi)_2S_3$.
83. Clausthalite, PbSe.
84. Tetradymite, $Bi_2(Te, S)_3$.
85. Vanadinite, $3(3PbO, V_2O_5) + PbCl_2$.

LIST OF ELEMENTS AND ATOMIC WEIGHTS.

Aluminium,	Al	27·08	Mercury,	Hg	200·23
Antimony,	Sb	120·11	Molybdenum,	Mo	95·95
Arsenic,	As	75·04	Nickel,	Ni	58·46
Barium,	Ba	137·08	Niobium,	Nb	94·03
Beryllium,	Be	9·10	Nitrogen,	N	14·04
Bismuth,	Bi	208·01	Osmium,	Os	198·16
Boron,	B	10·97	Oxygen,	O	16·00
Bromine,	Br	79·96	Palladium,	Pd	106·12
Cadmium,	Cd	112·08	Phosphorus,	P	31·03
Cæsium,	Cs	132·91	Platinum,	Pt	194·86
Calcium,	Ca	40·00	Potassium,	K	39·13
Carbon,	C	12·00	Rhodium,	Rh	104·14
Cerium,	Ce	141·50	Rubidium,	Rb	85·44
Chlorine,	Cl	35·46	Ruthenium,	Ru	103·97
Chromium,	Cr	52·30	Selenium,	Se	79·02
Cobalt,	Co	58·99	Silicon,	Si	28·07
Copper,	Cu	63·33	Silver,	Ag	107·93
Didymium,	Di	145·00	Sodium,	Na	23·05
Erbium,	Er	166·22	Strontium,	Sr	87·52
Fluorine,	F	19·03	Sulphur,	S	32·06
Gallium,	Ga	70·00	Tantalum,	Ta	182·61
Germanium,	Ge	72·32	Tellurium,	Te	126·62
Gold,	Au	196·69	Thallium,	Tl	204·19
Hydrogen,	H	1·0012	Thorium,	Th	233·04
Indium,	In	113·68	Tin,	Sn	117·97
Iodine,	I	126·86	Titanium,	Ti	49·14
Iridium,	Ir	193·02	Tungsten,	W	184·01
Iron,	Fe	56·01	Uranium,	U	239·80
Lanthanum,	La	138·52	Vanadium,	V	51·27
Lead,	Pb	206·91	Yttrium,	Y	89·61
Lithium,	Li	7·03	Zinc,	Zn	65·25
Magnesium,	Mg	24·19	Zirconium,	Zr	90·55
Manganese,	Mn	54·95			

HISTORICAL SKETCH OF BLOWPIPE ANALYSIS.

THE blowpipe was first used about the year 1660, when an instrument made of glass was employed in glass-blowing. A little later, 1679, KUNKEL (1638-1703) showed that the glass-blower's table could be utilized in chemical research, as in the reduction of metallic calces on charcoal. The instrument came somewhat more into use after its improvement by J. A. CRAMER (1710-1777), who made it of copper and added a spherical chamber to retain the moisture of the breath. Blowing with the mouth appears, however, to have proved a difficulty to many of his contemporaries, for in a second work Cramer describes an artificial blowing apparatus. Cramer mainly occupied himself with fusibility experiments, although he was the first to apply borax as a blowpipe reagent.

Much more successful efforts to employ the blowpipe in the service of chemistry were made in Sweden. The earliest experiments with this view appears to have been made by ANTON VON SWAB (1703-1768), and A. F. CRONSTEDT (1702-1765), who examined minerals and ores by this method. Cronstedt used as reagents borax, sodium carbonate, and microcosmic salt, and constructed the first portable blowpipe apparatus. The chemical relations of the minerals, as determined by aid of the blowpipe, enabled him to form a system of mineralogy, which he published in 1758 under the title, *Försök til Mineralogie.* This work first appeared anonymously, and was erroneously ascribed by contemporaries, among others by Linneus, to Anton von Swab. G. VON ENGESTRÖM (1738-1813) gave a more exact account of Cronstedt's use of the blowpipe as an appendix to his English translation of Cronstedt's book, which was published in London in 1770. This first complete guide to the use of the blowpipe became widely known by translation into other languages. The instrument, however, remained in few hands, as the application of the less perfect apparatus then in use could not be easily learned by reading alone without practical demonstration. This was changed, however, when BERGMANN (1735-1784), professor of chemistry at Upsala, whose investigations laid the foundation of our present method of inorganic analysis, applied himself to the blowpipe. His results began to be published in sections in 1773, but were first issued in collected form in 1779 under the title *Commentatio de tubo ferruminatorio.* Bergmann improved the blowpipe, taught the difference between the oxidizing and reducing flames, and examined a large number of minerals and inorganic compounds, in which work he had the valuable help of his pupil and, later, assistant, Gahn.

JOHANN GOTTLIEB GAHN (1745-1818) was so much devoted to blowpipe that he always carried one about with him, and submitted everything to it that came to him for analysis. As the result of this constant practice, he became wonderfully expert in the use of the instrument. Berzelius records that long before the ashes of plants had been found to contain copper, Gahn would clearly show the metallic copper obtained from the ash of a quarter sheet of paper. Gahn gave to the blowpipe the form it still retains (Fig. 1), introduced the use of platinum wire as support and cobalt solution as reagent, and discovered the reduction of metallic oxides with the aid of sodium carbonate on charcoal. Gahn published very little upon this subject, but he delighted in instructing his pupils and friends, amongst whom, Berzelius enjoyed his fullest confidence. At the request of Berzelius, Gahn wrote an account of the results of his work with the blowpipe for the *Lärbok i Kemien*, published by the former. Shortly before his death there also appeared in the eleventh volume of the *Annals of Philosophy* a paper bearing the title, *On the blowpipe: From a treatise on the blowpipe by Assessor Gahn of Fahlun.* In this memoir the behaviour of metallic compounds with sodium carbonate, borax, and microcosmic salt was dealt with in detail.

BERZELIUS (1779-1848) enriched and further improved the methods of blowpipe analysis ; he applied it over the whole region of inorganic chemistry and mineralogy, and published what he had learnt from Gahn as well as the numerous results of his own labours in his classical work, *Afhandling om Blasrorets anvandande i Kemien och Mineralogien* (1820). Through this work the blowpipe became the common property of all chemists and mineralogists.

PLATTNER (1800-1858) of Freiberg has rendered great service to the subject by perfecting the quantitative blowpipe analysis of silver ores first devised by HARKORT in 1827, and by the various methods he has described for the detection of bodies in combination. His *Probirkunst mit dem Löthrohr*, the later editions of which have been revised and supplemented by RICHTER, may also be fitly called a classical work.

BUNSEN, in his *Flammenreactionen*, published in 1866, made an entirely new departure in analysis by the dry way, by employing the flame of his gas burner instead of the blowpipe flame. Since charcoal, so much used as support in many important reactions, could not be employed with the new flame, Bunsen found it necessary to devise quite a different course of procedure.

Blowpipe analysis was early introduced into England. G. von Engeström's appendix to his translation of Cronstedt's work, published in London, has been referred to. It is the oldest outline of blowpipe analysis. Bergmann's *De tubo ferruminatorio* was translated into English by CULLEN in 1788. BLACK, TENNANT, FARADAY, TURNER, and WOLLASTON have contributed to the progress of blowpipe analysis; to the last named we are indebted for the use of platinum foil as support. Among the early English writers on this subject, GRIFFIN deserves especially to be mentioned for his excellent book on the use of the blowpipe in chemical and mineral analysis (1827), in which he also did full justice to Berzelius, which had not been done by Children in his translation of that master's blowpipe work.

Recent improvements in blowpipe analysis are not referred to in this historical sketch, but will be found fully described in the following pages.

BLOWPIPE ANALYSIS.

BLOWPIPE ANALYSIS.

CHAPTER I.

APPARATUS AND REAGENTS.

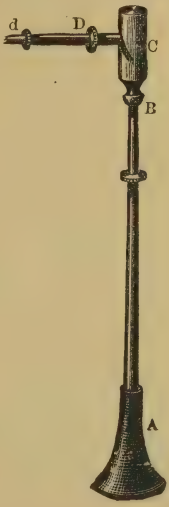

Fig. 1.

1. The *blowpipe* used for scientific purposes is shown in Fig. 1. It consists of three separate parts: a conical tube, AB, provided with a mouthpiece; an air-chamber, C, to retain the moisture of the breath; and a side tube, D, terminating in a platinum jet, *d*. The parts fit air-tight, and are held together by friction alone, so that the apparatus can be easily taken to pieces. The length of the blowpipe is usually about 200 mm., but this varies with the quality of the eyes of the possessor. Shortsighted persons require a shorter blowpipe, whilst for the longsighted a longer blowpipe is necessary. The platinum jet should have an opening of about 0·4 mm. diameter, but a second jet of 0·5 mm. is useful in cases where a stronger blowpipe flame is required. If the hole becomes stopped by soot it can be cleared by

heating over the flame of the spirit lamp or Bunsen burner. A form of hand blowpipe in common use in England, and known as Black's blowpipe, is shown in Fig. 2. It does not differ essentially from the form above described; the parts usually screw together, and the platinum nozzle can be removed for the purpose of cleaning.

Both forms of blowpipe are shown provided with a trumpet-shaped mouthpiece, which is generally preferred, although there is no objection to the oblong form of mouthpiece which is also largely used.

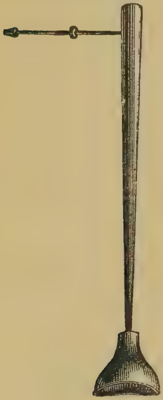

Fig. 2.

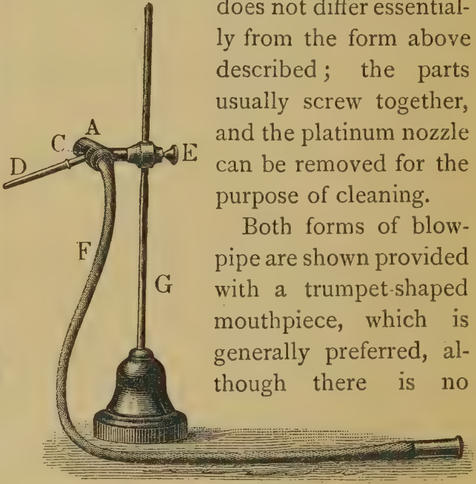

Fig. 3.

It is often advantageous to use a *stand blowpipe*, so as to leave both hands free to manipulate the substance under examination. Such an arrangement is shown in Fig. 3. The socket, A, surrounds the air-chamber of an ordinary blowpipe, whilst the side-tube, D, passes through the slot, C, in the socket. The caoutchouc tube, F, replaces the conical tube, AB, shown in Fig. 1. The socket is provided with a longitudinal slit, and clips the air-chamber with just sufficient tightness to hold the tube, D, at any desired inclination; whilst the whole apparatus, being moveable on the stand, G, can be fixed in any requisite position by means of the screw, E.

To relieve the cheek muscles *mechanical blowers* have been devised. Amongst these one of the most common is the hand-blower, Fig. 4, in which the blast of air is supplied by the intermittent compression of a caoutchouc bag, which is supplied with the requisite valve to admit air in the intervals when the pressure is removed. The air passes into an elastic reservoir, its return being prevented by a suitable valve, and a constant blast is thus obtained. The same principle is also applied in the manufacture of foot-blowers.

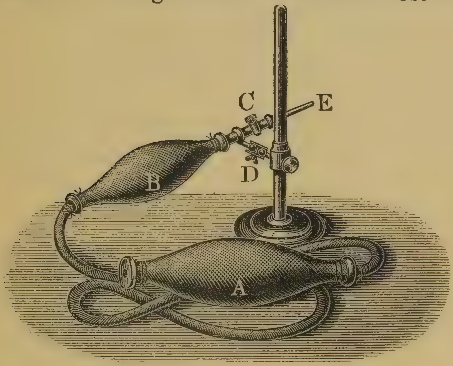

FIG. 4.

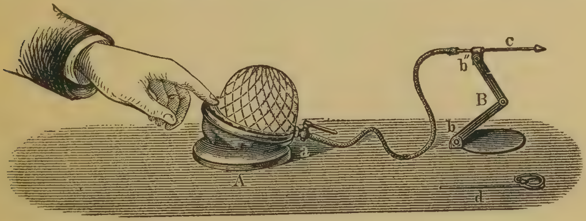

FIG. 5.

A portable and convenient form of blowpipe stand with hand-blower, manufactured by Mr. Fletcher, of Warrington, is shown in Fig. 5. The blast is supplied by the miniature hand-blower, A, similar in construction to the foot-blower of the same maker, and the stream of air is regulated by the tap, *a*. Connected with this by means of a caoutchouc tube is the stand, B, consisting of the blowpipe, *c*, held by a peculiar form of support, composed of brass rods, connected by knee-joints, *b b″*, which permit the blowpipe tube to be varied in height

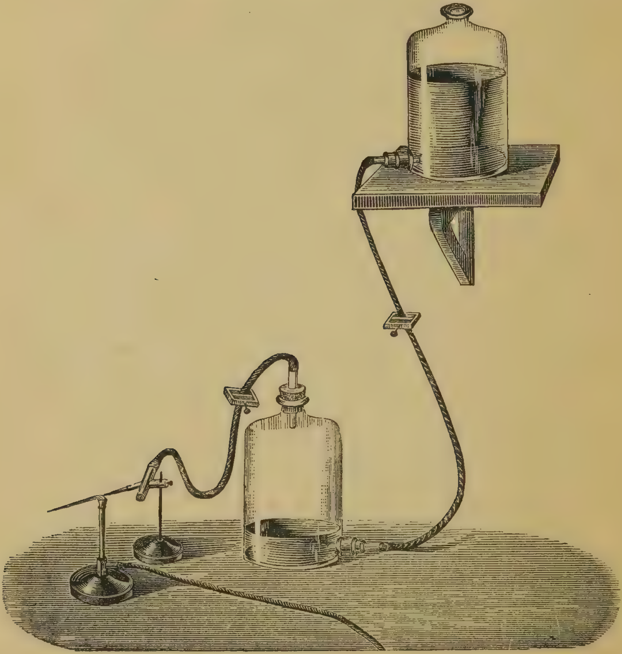

FIG. 6.

and inclination at will. The apparatus is provided with a second blowpipe tube, *d*, the end of which is bent round several times, and this becomes heated by the flame when the blowpipe is in use. A hot-air blast is thus produced, and the temperature of the resulting blowpipe flame is considerably increased. The apparatus is sufficiently small to be used while travelling, and it may even be put into the pocket.

In laboratories provided with a high-pressure water-service one of the numerous constructions of water-blast apparatus may be employed. This apparatus consists, in principle, of a water-supply pipe provided with a side tube, through which air is sucked by the current of water ; the current then passes into a chamber in which the air and water separate, the former passing out near the top to the blowpipe, and the latter flowing away from the bottom.

Most of the small filter pumps may also be converted into blowers by adding a capacious flask, provided near its bottom with a tubulature for the exit of the water, and with two bore holes in its stopper, of which one takes the pump and the other the blast pipe. The blast is regulated by suitable stop-cocks.

The author has devised a self-acting blowpipe apparatus, shown in Fig. 6, which may be readily constructed. It consists of two capacious bottles connected by a caoutchouc tube. One of them, filled with water, is placed on as high a shelf as can be conveniently reached, about a yard and a half being a suitable height, whilst the other is provided with a cork, bearing a tube communicating with the blowpipe. As the water passes from the upper to the lower bottle, the air in the latter is compressed and passes out to the blowpipe in a regular stream. Flasks of four litres capacity will supply a blowpipe jet of 0·4 mm. diameter with a constant stream for ten minutes. After this it is only necessary to change the flasks in order to continue the current. If bottles provided with holes near the bottom cannot be obtained, ordinary ones can be used by passing a tube to the bottom of each bottle, and then joining these as before. In this case it is necessary to exhaust the connecting tube, on changing the bottle, so as to cause the water to flow. The current of air can be regulated by placing a screw clip on either of the caoutchouc tubes.

Notwithstanding the convenience of these mechanical blowers, they are not so easily handled nor so certain in action as the common blowpipe, and they are only advantageously used in long continued work, in which blowing with the mouth would tire the muscles of the cheek. It may be further remarked, that only those who acquire expertness in the use of the mouth blowpipe will be able fully to realize the advantages of blowpipe analysis.

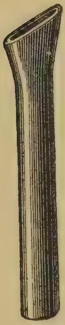

FIG. 7.

2. The most convenient blowpipe flame is obtained by taking a Bunsen lamp and placing within its tube a second tube, cut off obliquely at the upper end, and flattened so as to have an inside width of from 1 to 2 mm. (Fig. 7). The tube is about 100 mm. long, and, when in use, closes the air-holes of the burner. Unfortunately this flame cannot be employed when testing a substance for sulphur, as coal-gas frequently contains sufficient sulphur to vitiate the results.

For all accurate work the most suitable arrangement is Berzelius' blowpipe lamp as improved by Plattner (Fig. 8).

This consists of an oil vessel, *a*, on a stand, *c*, and provided with two openings which can be closed by screw-caps, the one opening being used for charging with oil, and the other, *d*, being fitted with a burner bearing a flat wick. Olive oil or refined rape oil is burnt.

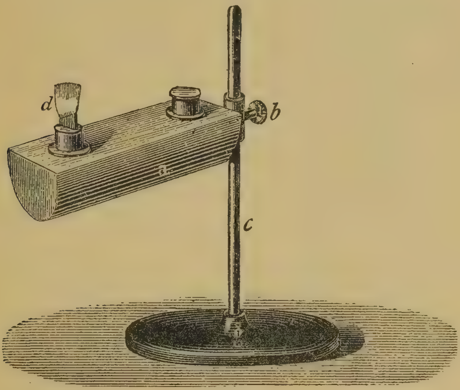

FIG. 8.

More recently lamps fed with fat, paraffin, or tallow have come into use with good effect; they are particularly suitable for travellers. Foster's lamp (Fig. 9) consists of a cylinder, *A*, to which the wick-holder, *B*, is soldered. The wick should be of open texture and laid in several folds. At first the flame is directed downwards upon the solid fat, etc., so as to melt the fuel, after which the lamp continues burning as long as the supply of fat is maintained. After each time of using the wick is drawn out a little with for-

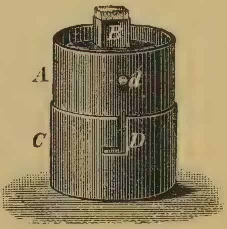

FIG 9.

ceps before the fat solidifies so as to be ready for further use. The cover, *C*, secured with a bayonet joint, *D*, *d*, serves as a support as shown. Fletcher's lamp (Fig. 10) consists of a paraffin-holder, A, with wick-holder, B, inserted, and cover, C, which also serves as a support, with which object it is weighted by the addition of a plate of lead. The screw, D, fastens C to A either as cover or as support.

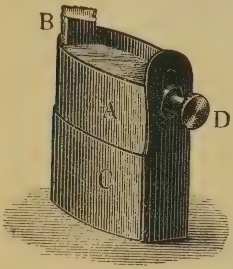

Fig 10.

A spirit lamp, with flat wick, which, however, must not be too small, may also be employed, if the alcohol be mixed with some compound rich in carbon; say, 1 part of turpentine or 3 of benzene to 12 parts of the alcohol. Such a lamp gives a high temperature, and does not require trimming so often as an oil lamp.

Up to Gahn's time candles alone were used for blowpipe flames, and for most purposes they are quite sufficient, but they are attended by the inconvenience that the candle is constantly decreasing in length. Thick stearin candles, the so-called carriage candles, are employed, and the wick is bent in the direction in which the blow-pipe flame plays; the guttering of the candle is prevented by surrounding it with tinfoil. Gas blowpipes are made, in which the lamp and blowpipe are combined. The jet tube is surrounded by another tube, and the gas is passed into the space between the two. The air and gas mix near to

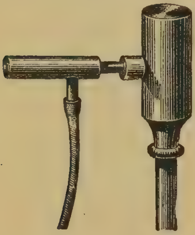

Fig. 11.

the open mouths of the two tubes, and the flame produced is oxidizing or reducing according as much or little air is mixed with the gas. Fig. 11 shows a common blowpipe, and Fig. 11 a stand blowpipe with this arrangement.

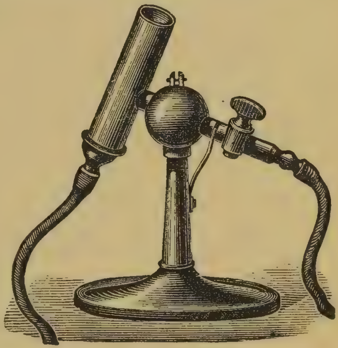

FIG. 12.

3. Charcoal, platinum, and glass are the principal substances used as supports before the blowpipe.

Of these *charcoal* is the most important on account of its low heat-conductivity and its reducing power. That from light woods, such as fir, is the best; it must be well burnt, and should neither smoke nor give off sparks.

It is sawn into pieces about 10 cm. long, 3 cm. wide, and 2 cm. thick, and only that side should be used which shows the rings of growth in section.

If good charcoal is not to be obtained blocks of artificial charcoal may be used, prepared by working up charcoal powder to a plastic mass with starch paste, moulding into shape, drying, and then heating in a closed crucible to faint redness, in order to decompose the binding material.

Small charcoal lozenges, resting on a support of unglazed porcelain or fireclay may also be used, the support being smoked in the flame.

Another substitute for charcoal is *aluminium plate*, which was first applied by Ross,[1] and which may be often used to advantage, especially for sublimates or incrustations. A piece about 120 mm. long, 40 mm. broad, and of the thickness of a sixpenny piece is taken, and one end is warmed and bent up so as to form a ledge 20 mm. deep, at a slightly acute angle to the body of the plate. On this ledge the assay is placed either directly or supported by a piece of charcoal, about 12 mm. square, and rather thicker than a penny-piece. The plate may be cleaned by means of wash leather with bone-ash and water, and lasts for a long time.

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[1] Ross, *Pyrology or Fire Chemistry*, London, 1875, Spon. Compare also Hutchings, *Chem. News*, xxxvi., 208, 217.

Platinum, which in the form of wire is very frequently used, is preferable to charcoal in oxidation tests as it exerts no reducing action, and the colour of beads can be more easily seen. Platinum wire, of the thickness of horse hair, is cut into pieces about 8 cm. long; one end of each piece is then bent into a small loop to serve as support to the flux to be used. Smaller pieces have one end fused into a drawn-out glass tube, which serves as handle. U-shaped loops, which are mainly used, form spherical beads, whilst O-shaped ones form flat lens-shaped beads, which in the case of deeply-coloured beads show the colour better. To have a clean stock of wires on hand they should be kept in a glass filled with water.

Platinum foil, which is not very largely employed, is used in pieces of about 50 mm. long by 15 mm. wide. A small platinum spoon is very useful in fusing substances with hydrogen potassium sulphate or nitre. A platinum spiral, from 2 to 3 mm. wide, made by coiling platinum wire around a lead pencil, may be used for the same purpose.

Glass tubes and small glass matrasses are very frequently employed, and should always be kept in stock.

For heating substances in air (roasting) glass tubes about 6 mm. in diameter and 100 mm. long, open at both ends, are used; whilst small matrasses, or glass tubes closed at one end, are employed for heating substances alone, without a current of air.

Gypsum slabs, about 10 cm. long by 4 cm. broad, are used on charcoal as supports for *iodide films*. To prepare them plaster of Paris is stirred up to a thin cream with water, poured on to a very slightly oiled glass plate, and divided into slabs of the size given above by means of a knife, after having thickened to a paste. When perfectly dry the mass can readily be removed from the oiled glass and broken up into pieces.

4. Of other apparatus the most necessary are:

An agate mortar, of from 40 to 50 mm. diameter.

Forceps with platinum points, which open by pressure.

Steel forceps.

A pair of steel cutting pincers, to cut off fragments from minerals.

A small hammer and anvil; both of hardened steel, and well polished.

A small magnetic needle.

A lens.

A spatula of polished iron.

Coloured glasses: a blue one, coloured by cobalt; a violet one, coloured by manganese; a red one, coloured by suboxide of copper; and a green one, coloured by iron and copper. Such glasses as are used for coloured windows are usually suitable.

A hollow glass prism containing indigo solution (Fig. 13). It should be about 150 mm. long, and about

35 mm. through at the stopper end. The solution is made by dissolving 1 part of indigo in 8 parts of fuming sulphuric acid, diluting with from 1,500 to 2,000 parts of water and filtering. In using the prism it is moved in a horizontal direction close before the eye, so that the light from a coloured flame passes through a gradually increasing thickness of the liquid.

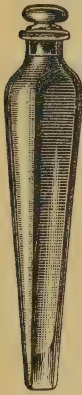
FIG. 13.

5. The reagents employed in blowpipe analysis should be as pure as possible.

Borax, $Na_2B_4O_7 + 10H_2O$. Commercial borax should be recrystallized, and the crystals, after being washed with distilled water, are then dried and powdered. On heating, borax fuses with intumescence to a glasslike mass, which dissolves metallic oxides, giving, in many cases, characteristic colours.

Microcosmic salt, $NH_4NaHPO_4 + 4H_2O$. This should give a perfectly clear bead on cooling after fusion; if the bead be not clear, the salt must be purified by recrystallization. This salt is employed for the same purpose as borax. By heat it is converted into sodium metaphosphate, which, with metallic oxides, sometimes yields more beautiful colours than borax, and in other cases gives quite different ones. As this reagent effervesces strongly on heating, and thus very easily drops from the platinum wire, its application is not quite so general as that of borax.

Sodium carbonate, Na_2CO_3, must be free from sulphate, for which it may be tested according to par. 172. Sodium bicarbonate may be substituted for the neutral carbonate.

Sodium carbonate is extensively employed as a reducing, dissolving, and decomposing agent.

Normal potassium oxalate, $K_2C_2O_4 + 2H_2O$, and especially **potassium cyanide**, KCN, are more powerful reducing agents than sodium carbonate, and are to be preferred in cases where a very powerful flame is required by the sodium carbonate. Potassium cyanide fuses easily, and it is usually employed in admixture with an equal amount of sodium carbonate.

Potassium nitrate, KNO_3, and **potassium chlorate**, $KClO_3$, are employed as oxidizing agents.

Hydrogen potassium sulphate, $HKSO_4$. The anhydrous salt, coarsely powdered, is kept in a well stoppered bottle. It serves to expel volatile substances, which may be recognized by their odour, or by the colour of their vapours ; it is also used to decompose substances.

Sodium hyposulphite (thiosulphate), $Na_2S_2O_3$, freed from its water of crystallization to a large extent, serves to convert metallic oxides into sulphides.

Iodine sulphide, I_2S_2, is prepared by heating together 40 parts of iodine and 60 parts of sulphur, and is used for the production of iodide films.

Fluorspar, CaF_2, free from boric acid, for which it may be tested according to par. 124, is used for the detection of lithium and boric acid. It is advisable to keep a mixture of one part of finely-powdered fluorspar and four parts of hydrogen potassium sulphate, in a special well-stoppered bottle.

Fused boric acid (anhydride), B_2O_3, a commercial article, is kept in small fragments, and is used for the detection of small quantities of copper in lead.

Silica, SiO_2, used in testing for fluorine, and also for sulphates and phosphates.

Cobalt nitrate, $Co(NO_3)_2 + 6H_2O$, in solution. One part of the pure salt is dissolved in ten parts of water. As this reagent is always applied in drops, it is well to have it in a bottle provided with a stopper in the form of a pipette, terminating at the upper end in a thistle-funnel, across which is stretched a piece of bladder or sheet indiarubber. By pressing and releasing the bladder, the pipette becomes charged with liquid, which can be expelled in drops by again pressing the bladder. Or the glass stopper may be extended in the form of a rod reaching nearly to the bottom of the bottle. Such bottles or others suitable for the purpose can be bought.

This reagent serves for the detection of certain earths and metallic oxides, which afford characteristic colours on being heated with it.

Copper oxide, CuO, can be easily prepared by heating copper nitrate in a porcelain basin; it is used for the detection of chlorine, bromine, and iodine.

Silver chloride, $AgCl$, made into a thick paste with water, is used for intensifying flame colorations. Fine iron wire is to be used with this reagent, and not platinum.

Magnesium wire, in pieces about 5 mm. long, serves for the detection of phosphoric acid.

Tin acts as a powerful reducing agent when applied to metallic oxides dissolved in beads. Tinfoil, cut into narrow strips, is rolled up tightly into thin pencils. On applying one of these to a heated bead on charcoal, a little of the tin dissolves; the bead is then strongly heated, for a short time only, in the reducing flame.

Stannous oxide, SnO, or Stannous chloride, $SnCl_2$, may be used instead of metallic tin, and the bead may then be supported on platinum wire without danger of destroying the support by the formation of a tin-platinum alloy.

Pure lead is easily obtained by placing a piece of zinc in a solution of lead acetate. The precipitated lead is repeatedly washed and dried between folds of filter paper.

Zinc in bar or in the granulated condition serves in conjunction with hydrochloric acid for the detection of several rare metals, whose solutions are reduced by the nascent hydrogen, yielding characteristic changes of colour.

Gold grains, of 50 to 80 mgr. weight, serve to test for nickel and cobalt.

Silver plate for the detection of sulphur compounds: a bright silver coin serves very well.

Test papers in narrow strips. Red and blue litmus paper for acids and bases, and brazil-wood paper for the detection of fluorine.

Sulphuric acid, H_2SO_4, in the concentrated state, is used in testing by means of flame-coloration.

Nitric acid, HNO_3, serves for the separation of silver from gold.

Hydrochloric acid, HCl, is used in testing by flame-coloration, in the detection of carbonic acid and ammonia, and together with zinc for the detection of several rare metals.

CHAPTER II.

THE OPERATIONS OF BLOWPIPE ANALYSIS.

6. Blowpipe analysis depends mainly on the indications afforded by substances when submitted to the oxidizing or reducing action of certain parts of a flame modified by a current of air. The action of the flame depends upon its structure. If a luminous flame such as that of a candle, for example, be carefully examined, it will be seen to consist of three principal parts:

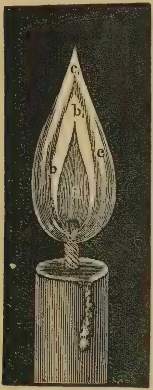

Fig. 14.

1. A dark core *a* (Fig. 14), which contains the gaseous products of decomposition yielded by the tallow or wax drawn up by the wick.

2. A strongly luminous zone, *bb′*, in which, in consequence of an insufficient supply of air, only partial burning of the combustible gases takes place. Oxygen from the air combines mainly with the easily combustible hydrogen, whilst the carbon is separated in a highly heated state, causing the luminosity of the flame.

3. An outer bluish mantle, *cc′*, in which the oxygen of the air is always present in excess, so that the separated

carbon is here completely burnt. The highest temperature exists in this part of the flame, and an oxidizable substance placed within it is speedily oxidized.

Besides these three zones a beautiful clear blue border is observable at the base of the flame. Although oxygen in excess is present here, still complete combustion does not take place, as the temperature is too low. Water and carbonic oxide are produced, the latter of which burns with a blue flame.

The flame of an oil lamp gives the same appearances as a candle. On the other hand, a non-luminous flame is produced by the Bunsen lamp, because the coal-gas which issues from a small jet within and near to the bottom of the tube, becomes mixed with air admitted through openings at the foot of the tube. Immediately on closing the air-holes the flame becomes a luminous one, of the same character as the candle flame.

In blowpipe work, only the outer *oxidizing* flame, *cc'*, and the inner luminous *reducing* flame, *bb'*, are considered.

The *reducing flame* is produced by bringing the blowpipe jet to the edge of the flame, and a little distance above the burner or the wick. A gentle current is then blown, which deflects the flame without completely passing into it, so that the flame is still slightly charged with glowing carbon.

In this way a yellowish luminous flame (Fig. 15) is produced, of which the most active part lies between *a* and *d*, and nearest to *a*.

The *oxidizing flame* is produced by passing the blowpipe jet a little further into the flame, up to about a third of the breadth of the flame, and blowing more strongly than before. A pointed non-luminous flame

(Fig. 16) is thus obtained, having an inner blue cone, before the point of which the hottest part of the flame is situated. Substances to be fused are placed in this part of the flame, whilst substances to be oxidized are placed somewhat further away, so that besides being strongly heated they may be freely exposed to the air.

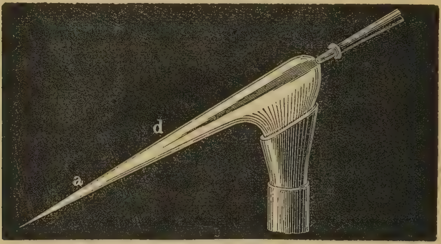

FIG. 15.

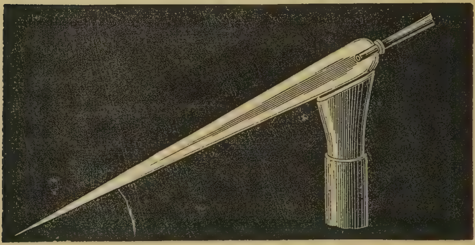

FIG. 16.

If the substance to be oxidized is supported on charcoal, a weaker blast must be employed, as otherwise a portion of the charcoal is burnt to carbonic oxide, which exercises a reducing action.

The inner blue cone of the oxidizing flame has a weak reducing action on account of the carbonic oxide it contains.

Whilst the oxidizing flame can be easily produced, some practice is required to obtain a good reducing flame. It is necessary that the reducing flame should be maintained unchanged for some time, and that the assay should be completely enveloped in it, in order to get good results ; but the assay should not be held too far in the flame, as soot may be deposited upon it, which will interfere with the reduction. As it is essential to success in blowpipe analysis that these two flames should be properly manipulated, careful practice is necessary in commencing to apply this art. As a test of good reduction, a borax bead containing manganese oxide may be employed ; this in the oxidizing flame becomes violet, or black if saturated with the oxide, whilst in the reduction flame it becomes almost colourless ; or a borax bead containing molybdic oxide may be used. In the reducing flame this is brown and opaque, but in a good oxidizing flame it becomes transparent and yellow, and when cold colourless.

The *blast* is produced by the muscles of the cheeks without co-operation of the lungs. The mouth is filled with air, which is pressed by the cheeks through the blowpipe, whilst the passage to the throat is stopped by the palate, and breathing is maintained through the nostrils. When the mouth requires refilling air is passed in from the full lungs, but without any effort on the part of the muscles of the breast. These operations are repeated continuously without interrupting the continuity of the blast. Only in this way can a constant current of air be maintained without prejudicially affecting the health. The requisite skill is soon obtained by practising breathing with distended cheeks, then taking up the blowpipe, and, whilst blowing, continuing to breathe neither quicker nor slower than the ordinary rate.

The blowpipe is held in the right hand so that the thumb and third and fourth fingers support the tube, whilst the first and second fingers rest upon it. The forearm leans for support against the edge of the table.

7. In examining substances before the blowpipe, it is necessary to take the various operations in some definite order. The following order is a convenient one.

Assay of the substance :—

1. In a glass tube closed at one end.
2. In an open tube.
3. On charcoal.
4. With borax and microcosmic salt.
5. As to flame coloration.
6. With reagents (sodium carbonate, cobalt solution, sodium hyposulphite, iodine sulphide, hydrogen potassium sulphate, zinc and hydrochloric acid).

As regards the amount of substance to be taken for each assay, a fragment the size of a grain of mustard seed will generally be found sufficient for most purposes. When, however, a metal is to be obtained by reduction, or in the case of heating in a glass tube, it is advantageous to take a somewhat larger quantity, for the greater the metallic bead or sublimate obtained the easier is it to judge of the nature of the substance. A portion of the substance to be examined should always be reserved for confirmatory tests, and to provide for unforeseen events. By way of precaution the lamp should be placed on a large sheet of paper, with turned-up edges, so that substances accidentally dropped can be easily found again.

ASSAY IN A GLASS TUBE CLOSED AT ONE END.

8. The substance is heated over a Bunsen lamp or spirit lamp, either in a small tube sealed at one end or in a small matrass. The heat is applied very gently at first, and is increased gradually to redness. By this treatment it is ascertained whether the substance is completely or partly volatile; or whether it suffers any other change.

I.—THE SUBSTANCE IS COMPLETELY OR PARTIALLY VOLATILIZED.

The following appearances are considered :

9. (1) **Water is given off.** Water is given off in the state of vapour which condenses on the cool part of the tube. This indicates water of crystallization [No. 39],[1] of hydration, or water mechanically included in the crystals of the substance [No. 33]. In the last case decrepitation takes place. The condensed water is examined with test paper ; an alkaline reaction indicates ammonia, an acid reaction the presence of a volatile acid, such as sulphuric, nitric, hydrochloric, or hydrofluoric acid.

10. (2) **Gas or Vapour is Evolved.** The most commonly occurring are :

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[1] These numbers refer to the list of *Examples for Practice* which precedes the text.

(a) *Oxygen* easily detected by the flaming of a glowing chip of wood held in the tube.[1] Oxygen indicates the presence of peroxides, nitrates, chlorates, bromates, or iodates [No. 35].

(b) *Sulphur dioxide*, detected by its odour of burning sulphur, and its action on blue litmus paper, mainly indicates the presence of sulphates or sulphites [No. 39].

(c) *Hydrogen sulphide*, known by its odour, arises from sulphides containing water.

(d) *Nitrogen tetroxide*, recognized by its reddish-brown vapours and characteristic odour, indicates nitrates or nitrites [No. 36].

(e) *Carbon dioxide*, a colourless, odourless and incombustible gas, which turns milky a drop of lime-water adhering to a watch glass, results from the decomposition of carbonates, or of such oxalates as contain a reducible metallic oxide.

(f) *Carbon monoxide*, which burns with a blue flame, indicates oxalates or formates; in the latter case the substance blackens.

(g) *Cyanogen*, from the decomposition of cyanogen compounds, is indicated by its peculiar odour and the carmine-red flame with which it burns.

(h) *Ammonia*, known by its odour and alkaline reaction, indicates ammonium salts [No. 27], or organic compounds containing nitrogen; in the latter case the mass usually chars, and cyanogen or empyreumatic oils are produced.

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[1] This reaction is not always obtained with a small quantity of the substance. In this case it is advisable to add a little sodium chloride and a drop of sulphuric acid. On warming chlorine is evolved, which is easily detected by its odour and its bleaching action on moist litmus paper.

(i) *Hydrofluoric acid*, which attacks the glass above the substance and gives it a dull appearance.

(k) *Chlorine*, *bromine*, *iodine* are indicated by their odour and the greenish-yellow, brown, or violet colour of their vapours. Iodine, when in not too small quantity, condenses and forms a greyish-black sublimate on the cool part of the tube.

II. (3) A sublimate is formed.

a. *WHITE SUBLIMATES* are formed by:

(a) *Ammonium salts.* The sublimate removed from the tube is placed on a piece of platinum foil; it is then warmed with a little caustic soda and a drop of water. Ammonia is evolved [No. 34].

(b) *Chlorides of mercury.* Mercurous chloride sublimes without previous fusion, whilst mercuric chloride first fuses. The sublimate is yellow when hot, but becomes white on cooling [Nos. 42, 43]. Mercuric oxide gives globules of mercury.

(c) *Antimony trioxide* fuses to a yellow liquid, and then sublimes to lustrous needle-shaped crystals [No. 12].

(d) *Arsenic trioxide* sublimes to octohedral crystals [No. 22].

(e) *Tellurium dioxide* behaves similarly to antimony trioxide, but requires a higher temperature, and yields an amorphous sublimate.

(f) *Osmium tetroxide* sublimes in white drops and has an extremely unpleasant, pungent odour.

β. *GREY* or *BLACK SUBLIMATES* with metallic lustre (the so-called metallic mirrors) are formed by:

(a) Metallic *arsenic* and such arsenides as contain more than one equivalent of arsenic to two equivalents of metal; also some sulpharsenides [No. 73]. If the tube be cut off below the mirror, and the latter be gently warmed, the peculiar garlic-like odour of arsenic will be perceived.

(b) *Mercury*, *amalgams* and some mercury salts. The sublimate consists of minute beads of mercury, which, by friction with a piece of copper wire, readily unite to larger globules [No. 44].

(c) Some *cadmium* alloys.

(d) *Tellurium.* The sublimate forms only at a very high temperature, and consists of small globules which solidify on cooling.

γ. *COLOURED SUBLIMATES* are formed by:

(a) *Sulphur* and certain *sulphides* which contain much sulphur. The sublimate is deep yellow to brownish-red when hot, and sulphur-yellow on cooling [No. 71].

(b) *Antimony sulphide* alone or in combination with other sulphides. The sublimate forms only at a very high temperature, and is deposited near to the test-piece; it is black whilst hot, and reddish-brown when cold [No. 70].

(c) *Arsenic sulphides* and some compounds of sulphides with arsenides. The sublimate is dark reddish-brown whilst hot, and red to reddish-yellow when cold [No. 76].

(d) *Cinnabar.* The sublimate is black, and without lustre, and gives a red powder on rubbing [No. 77].

(e) *Selenium* and some selenides. The sublimate forms only at a high temperature; has a reddish or black colour, and gives a dark-red powder; an odour of rotten horse-radish is also perceived [No. 83].

The non-appearance of the foregoing reactions is not sufficient to indicate with certainty the absence of the substances described; sulphur, arsenic, tellurium, and antimony occur in many compounds which give no certain evidence of the presence of these substances on heating in a closed tube.

II.—THE SUBSTANCE CHANGES WITHOUT VOLATILIZATION.

12. Many substances change in aspect only without changing in constitution on being heated in a closed tube; the following appearances should be noted:

1. **Change of Colour:**
    - (*a*) From white to yellow, becoming white again on cooling; zinc oxide [No. 10].
    - (*b*) From white to yellowish-brown, dirty pale yellow on cooling; tin oxide [No. 9].
    - (*c*) From white to brownish-red, yellow when cold; lead oxide (fusible) [No. 68].
    - (*d*) From white to orange-yellow or reddish-brown, pale yellow when cold; bismuth oxide (fusible).
    - (*e*) From red to black, red when cold; mercuric oxide (volatile).
    - (*f*) From red to black, red when cold; ferric oxide (non-volatile) [No. 60].
2. **Fusion:** alkaline salts.
3. **Carbonization:** organic substances.
4. **Phosphorescence:** alkaline earths, earths, zinc oxide, tin oxide, and many minerals.
5. **Decrepitation:** alkaline chlorides, galena, and many minerals.

ASSAY IN OPEN GLASS TUBE.

13. A fragment of the substance, or a little powder if the substance decrepitates, is placed about 12 mm. from one end of an open glass tube; the latter is slightly inclined, so that on heating it, a current of air passes through. The substance can thus be heated in a current of air, and roasting is effected; many substances thus give sublimates or gaseous products, whilst they remain unchanged when heated in a closed tube. Care should be taken to raise the temperature gradually, or the substance may be volatilized in an unoxidized state.

The air current can be increased or diminished at pleasure by inclining the tube more or less. By this means the following substances can be detected:

14. **Sulphur.** Sulphur dioxide is evolved, known by its odour and action on moistened blue litmus paper [No. 71].

15. **Arsenic.** A very volatile white sublimate of arsenic trioxide is formed, consisting of minute octohedral crystals. By gently heating, it may be driven from one part of the tube to another [No. 73].

16. **Antimony.** White fumes are evolved, which partly escape, and partly condense in the upper part of the tube. The sublimate is a white powder, and may, if consisting of pure antimony trioxide, be volatilized by heat. In most cases, however, the oxidation proceeds further, antimony tetroxide being formed, which is a non-volatile white powder [No. 1].

17. **Bismuth.** When not combined with sulphur, bismuth is converted into the fused brown oxide which, on cooling, becomes pale yellow [No. 2].

Mercury and **Amalgams** yield sublimates of metallic mercury in minute globules [No. 44].

18. **Tellurium** and **Tellurides.** These become oxidized to tellurium dioxide, which condenses in the upper part of the tube to a white non-volatile powder. On heating, this sublimate fuses to colourless drops, thus differing from an antimony sublimate.

19. **Selenium** and **Selenides.** These give the characteristic odour of rotten horse-radish, and yield a sublimate of selenium, which is steel-grey near to the substance, and red further away [No. 83].

ASSAY OF THE SUBSTANCE ON CHARCOAL OR ALUMINIUM PLATE.

20. The substance is laid in a very shallow cavity near to the edge of the charcoal, which is held somewhat inclined, so that when the flame is applied, an incrustation may be deposited on the charcoal in case the substance yields one. If the substance is in the form of a powder, or if it decrepitates, so that it must be reduced to a powder, it may be moistened with water and then be packed into the cavity. Or a small grain of borax may be first fused in the cavity and the powder or fragment placed upon it, whilst the borax is still in the melted state. The action both of the oxidizing and the reducing flame is tried, and the following points must be considered: fusibility, decrepitation, deflagration, intumescence, odour, flame-coloration, and more especially the formation of incrustations, and reduction to the metallic state.

Should *aluminium plate* be employed in the place of charcoal, the assay is laid on the narrow ledge near to the angle, and is heated by the oxidizing flame, which is

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held somewhat more inclined than with charcoal, and with its point 1-2 cm. from the object. This is essential, otherwise some incrustations would be reduced before they could be properly observed. A gentle blast is first applied, and then a stronger one until the incrustation ceases to increase. After examining the incrustation formed, the experiment is repeated with the assay supported on a small piece of charcoal (see p. 10). If no sublimate is obtained, the reducing flame is applied, first to the assay alone, and subsequently to the assay mixed with sodium carbonate.

In each case where a sublimate is obtained it is tested first with the peroxidizing flame, and then with the reducing flame. The former is done by bringing a good oxidizing flame to a distance of 3-4 cm. from the sublimate; and the latter by bringing the tip of the blue cone against the plate. The flame must be very pure, or soot will be deposited, which may be mistaken for a reduction effect, although such a stain may be known by its immediate disappearance in the oxidizing flame.

Sublimates are obtained in thicker layers on aluminium plate than on charcoal, partly because the vertical surface is better placed to intercept the metallic vapours, and partly because the plate does not become so hot just about the assay as does the charcoal. Owing to the grey colour of the plate, black or brown sublimates are readily seen, while on charcoal they are lost. As the aluminium plate becomes very hot, it requires to be held in a pair of tongs, or a special holder wrapped with flannel.

21. (1) **Fusibility.** Of non-metallic compounds, the following are *easily fusible:* most of the alkaline salts, and some of the salts of the alkaline earths; after being

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strongly heated, their residues have an alkaline reaction. Some are volatile, and cover the charcoal with an incrustation (see par. 40). The following are *infusible*, and without flame-coloration : compounds of the earths, and of the alkaline earths, silica, and many silicates. The earths and alkaline earths emit white light when heated, and are further examined with cobalt solution (par. 61).

Infusible with *change of colour :* zinc oxide, tin oxide, titanium dioxide, niobium pentoxide, tantalum pentoxide, and tungsten trioxide, which all attain a temporary yellow colour.

Of the metals, antimony, lead, cadmium, indium, tellurium, thallium, bismuth, zinc, tin, are *easily* fusible ; copper, gold, silver, are *more difficultly* fusible ; whilst iron, iridium, cobalt, molybdenum, nickel, platinum, osmium, palladium, rhodium, and tungsten are *infusible.*

(2) **Decrepitation.** Common salt and other haloid salts ; substances containing mechanically included water ; and many minerals.

(3) **Deflagration.** Nitrates, chlorates, iodates, bromates.

(4) **Intumescence.** Indicates substances containing water ; also borates and alum.

(5) **Odour.** Odour of sulphur dioxide indicates a sulphide ; odour of garlic indicates arsenic ; odour of rotten horse-radish indicates selenium.

22. (6) **Flame Coloration.** Many elements exhibit important and characteristic flame colorations which are better observed on platinum wire or in the platinum forceps, than on charcoal (see par. 42).

The most important colours are :

Yellow :	sodium salts.	
Red :	lithium . . .	carmine-red.
	strontium . .	scarlet.
	calcium . . .	yellowish-red.
Green :	copper . . .	emerald-green.
	barium . . .	yellowish-green.
	boric acid . .	finch-green.
	phosphoric acid	bluish-green.
	molybdic acid . .	yellowish-green.
Blue :	selenium . . .	cornflower-blue.
	arsenic . . .	bluish.
	lead	pale blue.
	copper chloride	azure blue, then green.
Violet :	potassium.	

23. (7) **Metal-reduction and formation of incrustation.** Many metallic oxides are reduced to the metallic state when treated on charcoal ; some are also partly volatilized, and others are so quickly vapourized, that none of the metal remains behind. These vapours are partly deposited on the cooler portion of the charcoal, forming incrustations which afford indications of very great importance as to the nature of the substance under examination. Care must be taken to avoid mistaking the ash of the charcoal produced wherever the flame plays, for an incrustation.

Most of the metallic oxides can be reduced by means of the reducing flame alone ; some, however, can only be thus reduced with the greatest difficulty, or not at all. To the last category belong the oxides of copper, cobalt, nickel, and iron. If, however, such a substance be made into a paste with sodium carbonate, or with a mixture of this and potassium cyanide, or if potassium oxalate be used, and the mixture treated in the reducing flame, then the reduction rapidly takes place. The application of these reagents does not interfere with the formation of incrustations.

In this way are obtained:

A. REDUCED METAL WITHOUT INCRUSTATION.

24. Gold, silver, and copper yield glistening malleable beads. Molybdenum, tungsten, platinum, palladium, iridium, rhodium, iron, nickel, and cobalt, give a grey infusible powder, which, in case of the three last-named substances, is magnetic.

To separate the reduced metal, the portion of charcoal saturated with the fused mass is cut out and ground with water in a small agate mortar, the liquid containing the light particles of charcoal being poured off. The malleable metals then remain as glistening spangles, and the brittle ones as metallic powder. Silver, gold, and copper can be distinguished by their white, yellow, and red colours; the remaining metals are discriminated by further treatment with borax and microcosmic salt.

B. REDUCED METAL WITH INCRUSTATION.

25. Antimony. Fuses easily, and covers the charcoal with white oxide situated not far from the assay-piece. The incrustation can be chased from one place to another by the oxidizing flame, but becomes black, and therefore disappears entirely under the reducing flame, the latter being thereby coloured a faint green. If metallic antimony be fused and heated to redness, it will burn for a short time even when left alone, giving off at the same time dense white fumes, which partly condense about the bead in the form of white crystals, having a pearly lustre. If the hot bead is dropped on to a sheet of white paper it breaks up into numerous smaller beads, which skip about their paths showing as a series of punctured lines [No. 1].

On aluminium plate the incrustation near to the assay-piece is yellow, further away pure white, and still further off bluish-white. Most antimony minerals yield it on the bare plate. The peroxidizing flame darkens the yellow colour momentarily, whilst the reducing flame instantly blackens all parts of the incrustation.

26. **Bismuth.** Fuses easily in both flames, and gives an incrustation which is orange-yellow when hot, and lemon-yellow when cold. The incrustation is often surrounded by a yellowish-white ring of bismuth carbonate. The incrustation lies a little nearer to the test-piece than in the case of antimony. It can be driven away by either flame, but differs from antimony and lead in imparting no colour to the reducing flame. The metallic bead is reddish white, brittle, and oxidizable [No. 2].

On the bare aluminium plate, little or no incrustation is obtained, but on the charcoal support a sublimate is produced which is yellow nearest the test-piece, passing into orange, and this into brown. Upon the ledge also a yellow sublimate is formed. The peroxidizing flame darkens the colour of the yellow and orange portions temporarily (compare lead), whilst the reducing flame blackens both.

27. **Lead.** Easily fusible; incrusts the charcoal in both flames with oxide, which is lemon-yellow when hot,

and sulphur-yellow when cold, and is surrounded by a white border of lead carbonate. The incrustation is about as far from the test-piece as in the case of bismuth; it can be chased away by either flame, the reducing flame becoming a sky-blue colour. The bead is grey, malleable, and oxidizable [No. 3].

On aluminium plate an incrustation is obtained only on using a charcoal support, as is the case with bismuth. The incrustation is coffee-brown, surrounding a pale-yellow ring, whilst on the ledge it is white. The yellow and white parts become brown in the peroxidizing flame, retaining this colour on cooling, whilst the brown colour in the case of bismuth disappears again on cooling. In the reducing flame all parts become black.

28. **Tin.** Fuses very easily, and in the oxidizing flame is converted into oxide, which may be blown away, and thus be made to appear as an incrustation. It is always found closely surrounding the assay-piece, is yellowish whilst hot, white when cold, and non-volatile in both flames. In the reducing flame the fused metal retains its metallic lustre. The bead is white, malleable, and very oxidizable [No. 4].

On aluminium plate a faint white incrustation is obtained by long heating on the charcoal support. The reaction on the support is the same as that on charcoal, just described.

29. **Silver.** As stated in par. 24, silver oxide is easily reduced to a brilliant metallic bead. If the bead, however, be heated for a long time in a strongly oxidizing flame, a dark-red incrustation is produced [No. 5]. If the silver contains lead or antimony, a yellow or white incrustation appears before the red one; if lead and

antimony be present at the same time, the incrustation has an intense rose colour.

On aluminium plate a brown incrustation, shading off into a lighter rim having a reddish tinge, is obtained. Below, near to the glowing edge of the charcoal, is a narrow strip, almost white, with faint pink tinge. The peroxidizing flame darkens all parts, whilst the reducing flame produces a circle of white, having the appearance of frosted silver. The behaviour of silver on aluminium plate is not very characteristic, as most silver ores give no reaction. The rose-coloured sublimate produced by silver in presence of antimony, coming out beautifully on aluminium plate, is however very characteristic.

30. **Gold.** On charcoal fuses, but gives no incrustation.

On aluminium plate an incrustation is produced after heating for some time with charcoal support. The gold is volatilized, and near to the charcoal a yellow film of gilding is deposited on the plate; beyond this is a strip of violet, and dotted all over are little specks of gold carried away mechanically.

31. **Thallium.** It fuses easily, and incrusts the charcoal with white oxide, which is driven away by slight warming; on contact with the flame, this latter acquires a green coloration, and the oxide disappears. The fused bead, which also colours the flame green, remains fluid for a considerable time after the flame is removed, and sometimes deposits a brown incrustation in its neighbourhood.

On aluminium plate, a copious white incrustation is first produced, which, as the temperature of the plate increases, is followed by a brownish one. In the peroxidizing flame the white part instantly turns reddish-brown. This change takes place more quickly than with lead, and the colour produced is very different. In the reducing flame all parts become black, and in the thickest portions little black beads can be seen with a lens.

32. **Indium.** It fuses easily, and forms an incrustation near to the test-piece, which is dark-yellow when hot, yellowish-white when cold, and is chased away with difficulty by the reducing flame, this latter acquiring a violet tint.

33. **Germanium.** On charcoal fuses to a brilliant bead which retains a rapid motion whilst in the flame, and evolves a white smoke producing a white incrustation. If the hot bead is dropped on to a sheet of paper it breaks up into numerous minute beads, which skip about as in the case of antimony, but the action sooner ceases owing to the higher melting point of germanium. Germanium oxide can be reduced to metal on charcoal in the reducing flame with some little difficulty, a white incrustation being formed at the same time. The application of any alkaline flux is to be avoided (WINKLER).

C. *INCRUSTATION WITHOUT METAL.*

34. **Arsenic.** It volatilizes without previous fusion, developing the characteristic garlic odour, and covers the charcoal at some distance from the test-piece, with a white incrustation, which disappears before both flames. The volatile incrustation imparts a clear blue coloration to the flame [No. 6].

On aluminium plate without charcoal support, a white sublimate is obtained, and a black stain is produced under the test-piece. On the charcoal support when much arsenic is present, there is also a good deal of grey-black sublimate, and there are large black stains on the ledge. In the peroxidizing flame the white portion is unchanged, but volatilizes rapidly as the plate gets hot. The grey and black portions are somewhat whitened and partly removed, but dark stains remain. The reducing flame volatilizes the sublimate rapidly, and the arsenic smell is very clearly perceptible.

35. **Zinc.** It fuses readily, and burns in the oxidizing flame with an intensely luminous greenish-white flame, and thick white fumes are evolved which, partly condensing on the charcoal, cover it with oxide which is yellow whilst hot, and white when cold. The incrustation becomes luminous under the oxidizing flame, but does not disappear [No. 7].

On aluminium plate without charcoal support, scarcely any incrustation is obtained. On a charcoal support a black film is obtained immediately the metal begins to burn, which directly gives place to the white oxide film. The peroxidizing and reducing flames have no action on the incrustation. Minerals containing zinc do not give the black incrustation.

36. **Cadmium.** It fuses easily, and burns in the oxidizing flame to brown oxide, which appears as brown fumes, and forms an incrustation about the test-piece, whilst the flame is coloured dark-yellow. This very characteristic incrustation is reddish-brown when cold, or in thin layers orange-yellow, and is easily volatilized by either flame without imparting colour to it. About the incrustation may be noticed a variegated border [No. 8].

On aluminium plate a dark-brown, almost black, film is obtained, which is not affected either by the peroxidizing or the reducing flame. On the edges of the charcoal support a little reddish-brown oxide is usually deposited.

37. **Selenium.** It fuses easily with disengagement of brown fumes; a steel-grey incrustation of feeble metallic lustre is deposited at a short distance from the assay. This disappears in the reducing flame, evolving a strong odour of rotten horse-radish, and imparting to the flame a fine blue colour [No. 83].

On aluminium plate with or without charcoal support a red incrustation is formed, and along with it some brown and white film. The peroxidizing flame whitens the red and brown parts, whilst the reducing flame gives to all parts a deep brown colour.

38. **Tellurium.** It fuses very easily, and coats the charcoal in both flames with tellurium dioxide. The incrustation is deposited near to the assay, has a white colour with reddish or dark-yellow border, and disappears in the reducing flame, the latter acquiring a green colour.

On aluminium plate, with and without the charcoal support, it forms close to the assay a strong incrustation of a blackish colour, which is brown in thin films. Where the deposit is thickest, it forms on short exposure to the flame, but better with the peroxidizing flame, a white layer of tellurium dioxide. The reducing flame colours all parts black; on longer blowing the deposit disappears where the flame plays upon it, this latter becoming thereby tinged green.

39. **Molybdenum.** The metal, a grey infusible powder, oxidizes in the outer flame, and gives a partly crystalline incrustation, which is yellow whilst hot, and

white when cold. By momentary exposure to the flame, the incrustation becomes a beautiful dark-blue colour (molybdenum molybdate); by longer heating it becomes dark copper-red, with metallic lustre (molybdenum dioxide) [No. 79].

On aluminium plate the sublimate (best obtained from molybdenite or ammonium molybdate) is produced without charcoal, and is light-yellow with white film. The peroxidizing flame darkens the colour somewhat, whilst the reducing flame, by momentary contact, produces a beautiful blue coloration.

40. Besides the above-named elements, there are other substances that yield white incrustations which may, with few exceptions, be driven away when played upon by the oxidizing flame, and which bear some resemblance to those described. The most important bodies of this kind are the following:

1. The sulphides of the alkalis, of lead, bismuth, antimony, zinc (incrustation non-volatile), tin (incrustation non-volatile), and the chlorine, iodine, and bromine compounds of ammonium, mercury, and antimony: they incrust the charcoal without previously fusing or sinking into the support.

2. The compounds of the alkalis with chlorine, bromine, iodine, and sulphuric acid: they fuse and sink into the charcoal before they evaporate.

3. The chlorine, bromine, and iodine compounds of lead, tin, bismuth, zinc, and cadmium, which fuse but do not sink into the charcoal before they incrust it.

EXAMINATION WITH BORAX AND MICROCOSMIC SALT.

41. Many metallic oxides possess the property of being at a high temperature dissolved by borax and by microcosmic salt with a characteristic colour. These fluxes serve, therefore, as valuable reagents for the detection of such oxides. Unoxidized metals, and those which are combined with sulphur, arsenic, or antimony, differ in this respect very materially from the pure oxides ; such compounds must therefore be subjected to a preliminary roasting on charcool, or in an open glass tube, so as to be converted into oxide before they can be thus examined. During the roasting, the finely powdered assay must not be heated too strongly, especially at first, or it may be fused, in which case oxidation can only proceed with difficulty.

Platinum wire is commonly used as support during this examination, as the colour of the glass formed upon it can easily be seen. Charcoal is employed, however, in the treatment of such oxides as are readily reducible to metal which attacks platinum.

In order to get a borax bead on the platinum wire, a small loop is formed on the end of the latter; this is then moistened or heated, plunged into the borax powder, and afterwards heated to fuse the adhering material. These operations are repeated until a sufficiently large bead is obtained.

The microcosmic salt bead is similarly obtained, but is more difficult of preparation, as the reagent froths up so long as water and ammonia are evolved, and very readily drops from the wire. Only small quantities at a time must therefore be taken up, unless the salt is previously fused to a bead on charcoal and then transferred to the wire.

To take up the substances, the perfectly colourless bead, whilst still soft or after being moistened, is brought into contact with a small quantity of the powder.

The substance is in the first place subjected to the oxidizing flame, and it is noticed whether the assay dissolves easily or with difficulty, quietly or with effervescence, and whether the bead is clear, opaque (enamel-like), or *coloured.* The changes which frequently take place during cooling are to be especially noted.

The bead is then brought into the reducing flame and the results compared with those previously obtained. The addition of a little stannous oxide or chloride to the bead, or of a small piece of tinfoil (the latter on charcoal), increases very materially the action of the reducing flame.

In order to observe the colour when strongly colouring substances are under examination, the bead whilst hot may be flattened with a pincette, or a circular loop may be formed on the wire, which will give a lens-shaped bead. The pearl may also be jerked off the wire whilst still hot into a porcelain dish, and after breaking it up a portion may be taken up on to a new pearl. The bead is jerked off the wire by striking the ball of the hand upon the table, the end of the wire being held over the dish.

Flaming. In many cases when a transparent bead is intermittently heated in the flame, or is repeatedly taken out of the flame, peculiar effects are obtained. This operation has received the name of "flaming."

Clear beads frequently become opaque, milk-white, or even coloured. This depends on the fact that certain compounds which dissolve at a high temperature separate out on being heated to a somewhat lower temperature, appearing as peculiar crystals, which are sufficiently well formed in most cases to be visible under the microscope when the bead has been flattened whilst hot, or when it has been dissolved in dilute acid so as to isolate the crystals.

The behaviour of the metallic oxides with borax and microcosmic salt is shown in the following tables. They are arranged according to the colour yielded by the hot bead when acted on by the oxidizing flame, and the reactions of the oxidizing and reducing flames are given in the same line. It may be here remarked that the microcosmic beads are often more beautiful than those of borax, and are occasionally different in colour.

The behaviour of the metallic oxides to these reagents is also given in the third and fourth columns of the table at the end of the book, where the metals are arranged in alphabetical order.

BEHAVIOUR WITH BORAX.

Contractions : fl. = by flaming ; c. bl. = continued blowing ; s. b. = saturated bead.

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
colourless	colourless	colourless	colourless	Silica
,,	,,	,,	,,	Alumina
,,	,,	,,	,,	Tin oxide
,,	colourless ; fl., opaque	grey ; c. bl., colourless	grey ; c. bl., colourless	Silver oxide
,,	,,	,,	,,	Tellurium dioxide
,,	,,	colourless	colourless ; fl., opaque	Baryta
,,	,,	,,	,,	Strontia
,,	,,	,,	,,	Lime
,,	,,	,,	,,	Magnesia
,,	,,	,,	,,	Beryllia
,,	,,	,,	,,	Yttria
,,	,,	,,	,,	Zirconia
,,	,,	,,	,,	Thoria
,,	,,	,,	,,	Lanthanum oxide
,,	,,	,,	,,	Tantalum pentoxide
,,	colourless	s. b., rose red	s. b., rose red	Didymium oxide
,,	colourless ; fl., opaque	colourless ; s. b., grey	colourless ; s. b., grey	Niobium pentoxide
colourless, s. b., yellow	,,	yellow to brown	yellow to brown ; s. b. fl., blue	Titanium dioxide

BEHAVIOUR WITH BORAX—*Continued.*

IN THE OXIDIZING FLAME.		IN THE REDUCING FLAME.		INDICATION.
Hot.	*Cold.*	*Hot.*	*Cold.*	
colourless ; s. b., yellow	colourless ; s. b., enamel white	yellow	yellowish-brown	Tungsten trioxide
yellowish	,,	grey ; c. bl., colourless	grey ; c. bl., colourless	Zinc oxide
,,	,,	,,	,,	Cadmium oxide
,,	colourless	,,	,,	Antimony oxide
yellow	colourless ; fl., opaque	,,	,,	Lead oxide
,,	colourless ; s. b., yellow and opalescent	,,	,,	Bismuth oxide
,,	greenish-yellow	brownish	emerald-green	Vanadium pentoxide
yellow to red	colourless to yellow	green	bottle-green	Iron oxide
,,	colourless to yellow, fl., enamel-like	,,	bottle-green ; s.b., fl., black	Uranium oxide
,,	,,	colourless	colourless; s.b., enamel-white	Cerium oxide
,,	colourless to opalescent	brown	opaque-brown[1]	Molybdenum trioxide
,,	grass-green	green	emerald-green	Chromium oxide
violet	reddish-brown	grey, c. bl., colourless	grey ; c. bl., colourless	Nickel oxide
violet, s. b., black	reddish violet, s.b., black	colourless	colourless	Manganese oxide
blue	blue	blue	blue	Cobalt oxide
green	bluish-green	colourless	brown ; c. bl., red	Copper oxide

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[1] In a strong reducing flame black particles of molybdenum oxide appear in the yellow bead.

BEHAVIOUR WITH MICROCOSMIC SALT.

Contractions: fl. = by flaming; c. bl. = continued blowing; s. b. = saturated bead.

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
silica skeleton	silica skeleton	silica skeleton	silica skeleton	Silica
colourless	colourless	colourless	colourless	Alumina
,,	,,	,,	,,	Tin oxide
,,	colourless; fl., opaque	,,	colourless; fl., opaque	Baryta
,,	,,	,,	,,	Strontia
,,	,,	,,	,,	Lime
,,	,,	,,	,,	Magnesia
,,	,,	,,	,,	Beryllia
,,	,,	,,	,,	Yttria
,,	,,	,,	,,	Zirconia
,,	,,	,,	,,	Thoria
,,	,,	,,	,,	Lanthanum oxide
,,	colourless	,,	c. bl., violet	Didymium oxide
,,	colourless; fl., opaque	grey; c. bl., colourless	grey; c. bl., colourless	Tellurium dioxide
colourless; s. b., yellow	colourless; s. b., milk-white	,,	,,	Zinc oxide
,,	,,	,,	,,	Cadmium oxide
,,	,,	,,	,,	Lead oxide
,,	,,	,,	,,	Antimony oxide

BEHAVIOUR WITH MICROCOSMIC SALT—*Continued.*

In the Oxidizing Flame.		In the Reducing Flame.		Indication.
Hot.	*Cold.*	*Hot.*	*Cold.*	
colourless ; s. b., yellow	colourless ; s.b., milk-white	grey ; c. bl., colourless	grey ; c. bl., colourless	Bismuth oxide
,,	colourless	colourless	colourless	Tantalum oxide
,,	,,	dirty green	blue[1]	Tungsten trioxide
,,	,,	yellow	violet[1]	Titanium dioxide
,,	,,	blue or brown	blue or brown[1]	Niobium pentoxide
yellow	yellow; s.b., opalescent	grey ; c. bl., colourless	grey ; c. bl., colourless	Silver oxide
,,	yellowish-green	dirty green	beautiful green	Uranium oxide
dark yellow	light yellow	brownish	emerald-green	Vanadium pentoxide
yellow to red | green	colourless to yellow or brown	yellow to red | greenish	colourless to reddish	Iron oxide
yellow to red	colourless	colourless	colourless	Cerium oxide
reddish to brownish red	yellow to reddish-yellow	reddish	yellow	Nickel oxide
reddish | dirty green	emerald-green	,,	green	Chromium oxide
violet	violet	colourless	colourless	Manganese oxide
blue	blue	blue	blue	Cobalt oxide
green	,,	dark green	brownish-red (turbid)	Copper oxide
,,	faint yellowish-green, almost colourless	dirty green	pure green	Molybdenum trioxide

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[1] Blood-red on addition of iron.

EXAMINATION WITH RESPECT TO FLAME COLORATION.

42. Many bodies, especially the alkalis and alkaline earths, are readily detected by the characteristic colours which they import to a non-luminous flame. The several salts of a flame-colouring element afford the same reaction, but with an intensity varying with the volatility of the salt used. The chlorides yield the best coloration, and for this reason the substance under examination is moistened with hydrochloric acid, or is treated with silver chloride and again heated.

In this examination the blue blowpipe flame may be used, or, what is much more convenient, the non-luminous flame of a Bunsen burner provided with a chimney. The assay is held by the platinum forceps or in a platinum wire loop whilst inserted in the flame; a liquid is carried in a flattened platinum loop. The indications are best seen against a dark back-ground, and in a room where there is neither direct sunlight nor much diffused light.

If several of the flame-colouring elements occur together, a mixed colour of intermediate character may result, or it may happen that the colour produced by one element quite overpowers the others; for example, if a sodium and potassium compound occur together, the violet colour due to potassium is quite invisible. To detect the elements in such a case the methods given in pars. 43 and 44 are applied.

The reactions given by the flame-colouring elements in the pure state, arranged according to the colours produced, are as follows:

Red Flames.

Lithium: carmine-red. Sodium salts obscure the reaction.

Strontium: scarlet-red[1]
Calcium: yellowish-red[1]
} Barium salts obscure the reaction.

Yellow Flames.

Sodium: orange-yellow.

Green Flames.

Copper oxide: emerald-green; after moistening with hydrochloric acid, blue.

Thallium: grass-green.

Phosphoric acid: bluish-green,
Boric acid: yellowish-green (finch-green).
} In their salts, after moistening with sulphuric acid.

Barium salts: yellowish-green.[1]

Molybdic acid: faint yellowish-green.

Tellurious acid: green, with evolution of fumes.

Antimony: faint-green.

Nitric acid: bronze-green, quickly disappearing.

Blue Flames.

Copper chloride: azure-blue, afterwards green.

Indium: indigo-blue.

Selenium: corn-flower blue, accompanied by odour of rotten horse-radish.

Arsenic: bluish.

Lead: blue.

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[1] Especially after moistening with hydrochloric acid.

Violet Flames.

Potassium: violet-red. Sodium and lithium salts obscure the reaction.

Cæsium: } like potassium.
Rubidium: }

43. In order to detect several flame-colouring elements when occurring together, it is easiest and best to use the spectroscope. If a coloured flame be observed by means of the spectroscope, bright coloured lines upon a dark ground are perceived. This arises from the fact that each element gives out a light peculiar to itself which is resolved into single rays by the prism of the spectroscope, and these rays form the lines seen in the apparatus. The lines vary in colour, position, and manner of grouping with each element: these characteristic differences form the basis of the most sensitive and exact method of analysis, the so-called *spectrum analysis.*

For blowpipe work the direct vision pocket-spectroscope such as that introduced by Browning is most suitable. The best instruments are provided with a scale; and also a comparison prism, by means of which the spectrum of an unknown substance can be observed simultaneously with that of a known substance, and the two compared.

Since the action of different instruments varies with the number of prisms, and the magnitude of the angle of refraction, the relative positions of the different lines vary with the instruments, and the scale readings of different observers are not directly comparable. For this reason the scale readings are reduced to wave-lengths, which is done by means of an easily constructed interpolation curve. The curve is drawn on paper ruled in small squares by setting off distances to scale (ordinates) along a vertical line conveniently numbered about 390 to 800 (millionths of a millimetre) for wave lengths, and on a horizontal line are the scale readings (abscissæ) of the instrument in use. The position of certain lines is exactly observed in the spectroscope, *e.g.*, Frauenhofer's C, D, E, b, F, G, and those of lithium and thallium; the numbers thus obtained are plotted on the horizontal scale of readings, and vertical lines are drawn through them to intersect horizontal lines drawn through the corresponding known wave length for each particular line; through the series of intersections thus obtained a curve is neatly drawn, by means of which the wave-length of any particular scale reading of the same instrument can be determined. For this purpose it is only necessary to run a vertical line, from the point in the horizontal line of abscissæ corresponding to the scale reading up to the curve, then a line run horizontally from this point of intersection to the vertical line of ordinates will give the corresponding wave length. The following lines with their wave-lengths will serve to construct the interpolation curve:—A = 760, B = 687, C = 656, D = 589, E = 527, b = 517, F = 486, G = 431, H = 397, Li = 671, Tl = 534.

In the following table are given the wave-lengths of line spectra such as are obtained by heating chlorides in the Bunsen flame, representations of which are given in the frontispiece. The heavy figures represent the most prominent lines and those which first appear. The Greek letters show the degree in which the various lines are characteristic.

SPECTRUM LINES OF THE MOST IMPORTANT FLAME-COLOURING ELEMENTS.

Element.	Violet Lines.	Blue Lines.	Green Lines.	Yellow Lines.	Orange Lines.	Red Lines.
Na	... ...	... ...	... ...	589		
K	404β	... ...	... ...	... ...	... ...	686, 768α
Li	... ...	... ...	... ...	... ...	610β	670α
Cs	... ...	456α, 459β	527, 530, 549 550, 551, 564	566	600, 621γ	670, 688
Rb	420α, 422β	... ...	512, 518, 520 526, 536, 542	567, 571	620, 629ε	780γ, 728δ
Ba	... ...	484	512β, 522α 537δ, 553ν	565, 570	603ε	626
Sr	... ...	460δ	... ...	... ...	601α, 616, 631	649, 656γ, 663β, 673
Ca	422	... ...	551β	570, 580, 592,	601, 614α	638
Tl	... ...	... ...	534			
In	410β	451α				

In using a spectroscope without scale, Frauenhofer's lines of the solar spectrum are used as a means of identification. It is scarcely necessary to remark that a knowledge of the spectra, founded on repeated observations, is better than any amount of description.

In applying the spectroscope, the substance to be examined is moistened with hydrochloric acid, taken up in a small loop on platinum wire and heated in the non-luminous Bunsen flame, or in the blue blowpipe flame. A spirit-lamp flame is not hot enough.

44. Many flame-colouring constituents can be successively detected without the spectroscope, as Merz[1] has shown, by the employment of coloured glasses, and by taking advantage of the differences in volatility of the substances.

The action of coloured glasses, which are held close to the eye when being used, depends on the fact that they only transmit certain rays, all others being absorbed. Red glass, for example, stops all rays except red ones; and blue glass stops certain red and green rays together with the whole of the yellow. In the case of a flame coloured by a mixture of sodium and potassium salts, a blue glass absorbs the yellow rays, due to sodium, and allows only the violet rays, due to potassium, to pass through.

In order best to observe the successive reactions afforded in consequence of the varying volatility of the different constituents of a mixture, the substance is first brought just into the border of the flame, then into the mantle, and lastly into the hottest part of the flame.

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[1] G. Merz: Flammenfärbungen, *Journ. prakt. Chemie*, Bd. 80, p. 487.

The following three kinds of reactions are thus obtained :[1]

(1) *Border colours*, which are formed outside of the flame itself and are only yielded by the most volatile substances. They are obtained by holding the platinum loop outside the lower part of the flame, and parallel with its axis, at a distance of from 1 to 2 mm.

(2) *Mantle colours*, which make their appearance in the outer non-luminous part of the flame. They are obtained by holding the loop vertically and about 1 mm. off the flame.

(3) *Flame colours*, which extend over the greater half of the whole flame ; they are obtained by holding the loop horizontally in the hottest part of the mantle.

All flame-colouring substances may, according to their volatility, be arranged in three classes : (1) certain acids, (2) alkalis, and (3) alkaline earths ; to which we may add one of the heavy metals, copper.

If substances be brought into the flame in the manner given above, we may detect

I.—THE ACIDS.

45. (a) *Nitric* and *nitrous acids* give a bronze-green border colour, with, as a rule, an orange-coloured margin. The assay is first dried in the flame, and then either moistened with dilute hydrochloric acid or with a solution of hydrogen potassium sulphate according as nitrous or nitric acid is looked for. Ammonium and cyanogen compounds give the same reaction but somewhat weaker.

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[1] The flame of a Bunsen gas lamp is much to be preferred for these reactions, as blowing is dispensed with, and the whole attention can be given to the reactions, which, as a rule, require close observation. If coal gas be not at hand, a stand blowpipe will be useful, as both hands must be free in making these experiments. The substance is held in the one hand and the coloured glass in the other.

46. (b) *Phosphoric acid* yields a greyish yellow-green border colour after moistening with sulphuric acid. In presence of boric acid, phosphoric acid can only be detected by the green flame produced on heating in a hydrogen flame after moistening with a solution of hydrofluosilicic acid. For this purpose the hydrogen is emitted from a platinum jet, for example, the side tube of a blowpipe [No. 27].

47. (c) *Boric acid* gives a beautiful green mantle colour, which is so intense that the acid can be detected in presence of a considerable amount of phosphoric acid. Borates require to be previously decomposed by sulphuric acid [No. 26].

48. (d) *Molybdic acid* gives a yellowish-green flame colour, similar to that yielded by barium salts [No. 79].

49. (e) *Hydrochloric acid*, or a chloride moistened with sulphuric acid, yields a very faint greenish mantle colour; the coloration appears momentarily only, and generally escapes detection.

II.—THE ALKALIS.

50. (a) *Potassium* gives a greyish-blue mantle colour and a rose-violet flame colour. The colour appears reddish-violet through blue glass[1] (detection in presence of sodium), violet through violet-coloured glass, and bluish-green through green glass. Potassium is detected in the presence of lithium by means of green glass, of a considerable thickness of blue glass, or by the indigo-prism. The potassium flame is visible through all thick-

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[1] Cartmell, *Phil. Mag.*, May 1858, p. 328.

nesses of the prism, whilst the lithium flame is invisible after a certain thickness is reached. This point is ascertained by a previous experiment with lithium chloride and is marked on the prism, the part beyond this only allowing potassium rays to pass.[1] Instead of indigo solution, Cornwall recommends an aqueous solution of potassium permanganate, which will serve for months if the prism be kept vertical so that the solution does not come into contact with the cork or india-rubber stopper. Any brown deposit which may form can be readily removed by emptying out the liquid and washing the flask with a little concentrated hydrochloric or sulphuric acid.

The assay is moistened with sulphuric acid, dried and again brought into the flame for a *short* time. Organic compounds, which become carbonized, must be previously decomposed by ignition as they also give a violet flame, and the red and violet rays of the glowing platinum wire must not be mistaken for the potassium reaction; in the latter case the coloration always ascends from the assay towards the point of the flame.

51. (b) *Sodium* gives an orange-yellow flame colour, which in quantity appears blue through blue glass but which is invisible when less in amount. Viewed through green glass the flame has an orange-yellow colour, characteristic of sodium in all its compounds. If a crystal of potassium bichromate be held near to the sodium flame the former becomes quite colourless, and a red smear of mercuric iodide on paper becomes white with a faint tinge of fawn colour.

The assay is moistened with sulphuric acid, dried, and then held in the hottest part of the flame [Nos. 33 and 58].

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[1] Bunsen, *Ann. Chem. Pharm.*, CXI., p. 267.

52. (c) *Lithium* yields a carmine-red flame colour which appears violet-red through blue glass, and carmine-red through violet glass, but is invisible through green glass. In the presence of sodium, lithium is detected by means of the blue glass. In the presence of potassium the following method, given by Bunsen,[1] may be employed. The assay is brought into the melting space of a Bunsen gas-lamp, and this flame is compared simultaneously, through an indigo prism, with one obtained from a pure potassium salt held in the corresponding part of the flame opposite to the assay. Through the thinnest layers of the solution the lithium flame appears redder than the pure potassium flame; through thicker layers the flames appear equally red, when the proportion of lithium to potassium is very small. If lithium predominates in the assay the intensity of the red flame diminishes rapidly as the prism is moved; whilst the pure potassium flame is scarcely weakened at all. In this way a thousandth part of lithium in a potassium salt can be detected. Sodium, when not present in very large excess, modifies these effects but slightly [No. 59].

Potassium and lithium are not likely to be confounded with strontium, if the assay be treated as described under potassium, since strontium compounds are not volatilized at the low temperature thus obtained.

III.—THE ALKALINE EARTHS.

The assay is repeatedly moistened with sulphuric acid, dried and placed in the hottest part of the mantle. After all alkalis are volatilized the following reactions appear:

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[1] Bunsen, *loc. cit.*

53. (a) *Barium* affords a yellowish-green flame colour which, through green glass, appears bluish-green. If the green gives place to a red flame colour (calcium, brick-red; strontium, scarlet-red) the assay is repeatedly moistened with hydrochloric acid and brought, whilst still moist, into the hottest part of the flame. If no bluish-green colour appears when viewed through green glass, even when the assay is spitting, the examination for calcium is proceeded with.

54. (b) *Calcium* gives a yellowish-red flame colour, which during the spitting of the assay (*i.e.*, when the last portion of hydrochloric acid is disappearing) appears finch-green through green glass. Strontium gives under these circumstances a momentary faint-yellow colour [No. 29].

55. (c) *Strontium* is known by the purple to rose colour which appears through blue glass as the assay spits in the flame after being moistened with hydrochloric acid. Under the same conditions calcium gives a faint greenish-grey [No. 53].

IV.—COPPER.

56. *Copper chloride* [No. 40] gives a sky-blue flame colour; the nitrate yields a pure green one. All doubtful cases can be solved by the combination of the two reactions [No. 69].

57. The remaining flame-colouring elements, as arsenic, tin, lead, mercury, and zinc, afford, especially as chlorides, more or less intense bluish to greenish mantle colours, which, however, are of no great value in analysis. As a rule the appearance of these colours can be prevented by moistening with sulphuric acid. It is best, however, to expel on charcoal the metals which give an incrustation,

before testing for alkalis or alkaline earths by flame-coloration.

58. In order to detect the alkalis in silicates it is sufficient to decompose the assay on platinum wire with some pure gypsum. If, on the contrary, the alkaline earths are sought for, the decomposition must be effected by means of sodium carbonate. The substance is fused with the reagent in a platinum spoon, the fused mass extracted with water, and the residue treated with hydrochloric acid, when silicic acid separates out, the solution being examined in the flame.

EXAMINATION WITH REAGENTS.

Reactions with Sodium Carbonate.

59. In addition to its employment for the reduction of metallic oxides as described in par. 23, sodium carbonate is also applied in the fused condition to certain substances which under this treatment yield compounds which are fusible in some instances, and infusible in others. The substance in a finely powdered condition is mixed with the carbonate, moistened slightly, and placed in a cavity made in the charcoal. It is then heated, first gently, to expel the moisture, and afterwards as strongly as possible.

The following oxides cause effervescence and yield fusible compounds:

Silica fuses to a transparent glassy mass, which remains clear on cooling if the carbonate has not been added in too great excess [No. 51].

Titanium dioxide fuses and gives a glass which is dark yellow when hot; on cooling this becomes turbid and crystalline.

Tungsten trioxide and *molybdenum trioxide* are absorbed by the charcoal after expulsion of the carbonic acid [Nos. 20 and 16].

Tantalum dioxide, *vanadium pentoxide* and *niobium pentoxide*, also form fusible compounds and sink into the charcoal.

Besides these oxides, *barium* and *strontium* salts form fusible compounds with sodium carbonate, and are absorbed by the charcoal. *Lime*, *magnesia*, *alumina*, *zirconia*, *thoria*, *yttria*, and *beryllia*, as well as *cerium* and *uranium oxides*, are not attacked; they remain behind unchanged whilst the carbonate of soda sinks into the charcoal.

60. Sodium carbonate is also used for the detection of:

(a) *Sulphur*, *selenium*, and *tellurium compounds*, which give with it a fused mass, yielding a black or brown stain when laid on a silver coin and moistened [No. 71].

(b) *Manganese* and *chromium*, which, with the carbonate alone, or better with addition of nitre, yield coloured masses. Manganese compounds yield a green mass of manganate, whilst the chromium compounds give a yellow mass of chromate [Nos. 62 and 17].

A detailed account of all the reactions obtained with sodium carbonate is given at the end of the book in the table on the behaviour of the metallic oxides.

Reactions with Cobalt Solution.

61. Substances which, after heating in the oxidizing flame on charcoal appear white, or almost white (see par. 21), are moistened with a solution of cobalt nitrate and again strongly heated. If the substance is porous enough to absorb the liquid it is moistened with a drop of the solution, and brought into the flame in the platinum forceps. In other cases it is pulverized, moistened with a drop of the solution, and placed in a cavity in the charcoal and heated. The colour is only seen with certainty on cooling and in the daylight.

Amongst the earths alumina and magnesia give specially characteristic reactions; a blue colour of greater or lesser purity, but without lustre, indicates alumina [No. 21], a flesh-red colour indicates magnesia [No. 55]. These reactions are obscured by the presence of coloured metallic oxides which as a rule give grey or black masses. It is to be observed that some silicates, borates, and phosphates, yield blue colours on heating with cobalt solution; the salts of these acids with the alkalis form fusible masses, whilst the salts of the earths are infusible.

Of the heavy metals, zinc and tin compounds yield characteristic colorations. The assay is first heated in the reducing flame on charcoal, the incrustation formed is then moistened with the solution, and carefully ignited in the oxidizing flame. Zinc oxide gives a beautiful yellowish-green mass; with tin oxide the product has a bluish-green colour [Nos. 10 and 9].

Besides the above-mentioned bodies there are others which when ignited with cobalt solution exhibit a change in colour; the coloration being, however, not sufficiently characteristic to serve for their detection. These are included in the following tabular view:

The colour produced is

Blue:	*Alumina;* beautiful blue, infusible.
	Silica and silicates; faint bluish; with large excess of cobalt solution black. Thin splinters fuse in the hottest flame to reddish-blue glass.

	Phosphates, *silicates*, and *borates* of the alkalis give a blue glass.
Green :	*Zinc oxide ;* *Titanium dioxide ;* } yellowish-green.
	Tin oxide ; bluish-green.
	Antimony oxide ; dirty green.
Flesh-red :	*Magnesia ;* pale flesh-red.
	Tantalum dioxide ; hot, light grey, *cold*, flesh-red.
Violet :	*Zirconia ;* dirty violet.
	Magnesium phosphate and *arsenate* fuse and become violet-red.
Brown :	*Baryta ; hot*, reddish-brown ; *cold*, colourless.
Grey :	*Beryllia ;* light bluish-grey.
	Niobium pentoxide ; brownish-grey.
	Lime ; grey.
	Strontia ; dark-grey to black.

Reactions with Sodium Hyposulphite (Thiosulphate).

62. All the metals precipitated by hydrogen sulphide in the wet way yield the sulphide reaction in the dry way when the substance is heated with powdered sodium hyposulphite. The mixture of assay and reagent is best heated in glass tube closed at one end. After the decomposition of the hyposulphite, which is easily recognized by the odour of hydrogen sulphide produced, the colour of the fused mass, due to the sulphide formed, is very readily seen. In many cases the reaction is accelerated by the addition of a small quantity of oxalic acid.

As the hyposulphite contains a considerable amount of water of crystallization, the greater portion of this should be previously expelled, or the glass tube should be held horizontally to prevent cracking, and have its mouth stopped with a little cotton wool on first heating.

Another method of producing these reactions consists in mixing equal parts of assay and reagent with a drop of water to form a paste, which is heated on a gypsum slab, or failing that on the aluminium plate, in a good reducing flame with a gentle blast. The same sulphide reactions are obtained as in the glass tube with closed end, along with other reactions (flame coloration, film formation), which aid as confirmatory indications.

The sulphide reactions of the metals are given in the following table, together with the borax reactions. The two methods supplement each other exceedingly well :

Metallic Oxide.	*Reaction with* $Na_2S_2O_3$.	*Reaction with Borax on Platinum Wire (the bead cold).*	
		Oxidizing Flame.	*Reducing Flame.*
Antimony oxide	first red, then black,	colourless	grey to colourless.
Arensic ,,	yellow	—	—
Bismuth ,,	black	colourless	grey to colourless.
Cadmium ,,	*hot*, cinnabar red *cold*, yellow	,,	,,
Chromium ,,	green	grass-green	emerald-green.
Cobalt ,,	black	blue	blue.
Copper ,,	,,	bluish-green	brown.
Gold ,,	,,	reduced without dissolving.	
Iron ,,	,,	yellow	bottle-green.
Lead ,,	,,	colourless	grey to colourless.
Manganese ,,	light green	reddish-violet	colourless.
Mercury ,,	black	—	—
Molybdenum,,	brown	colourless	brown.
Nickel ,,	black	reddish-brown	grey to colourless.
Platinum ,,	,,	reduced without dissolving.	
Silver ,,	,,	colourless	grey to colourless.
Thallium ,,	,,	,,	colourless.
Tin ,,	brown	,,	,,
Uranium ,,	black	yellow	bottle-green.
Zinc ,,	white	colourless	grey to colourless

Reactions with Iodine Sulphide.

63. The assay is mixed with an equal volume of iodine sulphide, placed near one end of a gypsum slab and heated in the oxidizing flame.[1] The incrustations obtained have the following colours :—

Antimony,	Orange-red.
Arsenic,	Buff.
Lead,	Chrome-yellow.
Tin,	Brownish-yellow.
Silver,	*Hot*, light yellow ; *cold*, faint greyish-yellow (close to the assay).
Mercury,	Yellow and scarlet ; the yellow becomes scarlet on standing, and more quickly when rubbed.
Thallium,	A series of colours—first, orange, followed by yellow iodide, then white, light blue, green, and black.
Selenium,	Reddish-brown.
Tellurium,	Purplish-brown.

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[1] *Wheeler* and *Luedeking*. Trans. St. Louis Academy of Science, 1886, Vol. VI., p. 676. Iodine films were first described by *Bunsen* (1866) in his Treatise on Flame Reactions (comp. §§ 73, 75, etc.), and, with other reactions, arranged as a valuable analytical method in which the Bunsen flame is employed. *Kobell* (1872) applied the iodine reaction with the blowpipe flame by means of potassium iodide and sulphur. *Haanel* (1882) essentially extended this method by employing hydriodic acid, and a gypsum slab as support. *Moser* worked with the same reagent, whilst *Wheeler* and *Luedeking* (1885) substituted the more easily obtained iodine tincture. With the object of replacing the liquid reagent by the more portable solid, *Hutchings* employed copper iodide with sulphur (on the aluminium plate). *Casamajor*, with good results, used silver iodide (in open glass tubes about 4 in. long), and more recently *Wheeler* and *Luedeking* introduced sulphur iodide. The last and most convenient procedure is described in detail above.

Bismuth,	Chocolate-brown, sometimes fringed with red near the assay (light red when exposed to ammonia fumes).
Cobalt,	Greenish-brown, with green border; brown film transient, passing to faint green, especially when breathed upon.
Molybdenum,	Deep ultramarine blue, close to the assay. (The film is an oxide Mo_2O_5.)
Tungsten,	Faint greenish-blue (oxide W_2O_5).
Copper,	White.
Zinc,	White.
Cadmium,	White.

The last three metals are heated on charcoal, or if a gypsum slab is used it must be smoked previously, otherwise the white film is not visible. The brown film produced by the reagent alone disappears completely on a few minutes' exposure. With this test there is formed more or less of a dark film near to the assay, a sulphide deposit, which owes its formation to the excess of sulphur necessarily present to decompose the assay.

Owing to the similarity of many of the films, this process, notwithstanding its delicacy, is not well adapted for the examination of mixtures, but serves rather for confirmatory tests. The test for molybdenum is very characteristic, and the method is valuable in affording a test for tin in presence of zinc. It is advantageous to compare these films with the sulphide films described in the last section; if these have been produced on gypsum, they can be converted directly into iodides by heating with iodine in the oxidizing flame.

Reactions with Hydrogen Potassium Sulphate or Concentrated Sulphuric Acid.

64. For the detection of volatile acids a small quantity of the substance is heated with hydrogen potassium sulphate or with concentrated sulphuric acid (in the latter case, however, not to the boiling point of the acid), and the following appearances are looked for :

(1) **A coloured gas is evolved.**

(a) *Nitrous fumes*, known by their reddish-brown colour and characteristic odour; evolved from nitrates and nitrites. With nitrates the reaction is promoted by the addition of copper filings.

(b) *Chlorine tetroxide;* yellowish-green, smelling like chlorine, bleaching litmus paper, and explosive. The tetroxide is produced from chlorates by this treatment.[1]

(c) *Iodine*, from iodides, is known by its violet vapours, which colour paper smeared with starch-paste blue. Iodates[1] give this reaction after the addition of ferrous sulphate.

(d) *Bromine;* reddish-brown vapour, with pungent, unpleasant odour, and turning starch-paste yellow; yielded by bromides and bromates.[1] The colour of the vapour is best seen on looking down the tube.

(2) **A colourless odorous gas is evolved.**

65. (a) *Sulphur dioxide*, from sulphites and polythionates, is easily known by its odour.

(b) *Hydrochloric acid*, from chlorides, known by its odour and by the cloud of ammonium chloride which is formed when a glass rod moistened with ammonia solution is held near to the tube.

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[1] The chlorates, iodates, and bromates detonate when heated on charcoal.

(c) *Hydrofluoric acid*, from fluorides, has a very pungent odour, and strongly corrodes glass.

(d) *Hydrogen sulphide*, from sulphides, blackens paper moistened with lead acetate.

(e) *Cyanic acid*, from cyanates, has a characteristic pungent odour; it brings tears into the eyes, and renders lime-water turbid.

(f) *Acetic acid*, from acetates, is known by its pungent odour, and also by yielding fragrant acetic ether on heating with sulphuric acid and alcohol.

(3) A colourless odourless gas is evolved.

66. (a) *Carbon dioxide* is expelled from its salts with effervescence; it renders lime-water turbid.

(b) *Carbon monoxide*, which burns with a bluish flame, may arise from oxalates, formates, cyanides, ferrocyanides, ferricyanides.

(c) *Chromic acid* evolves oxygen, and the liquid turns brown or green.

(d) *Organic acids*, recognized by the blackening due to the separation of carbon.

The acids which cannot be detected by the above methods, though easily detected in other ways, are: sulphuric, phosphoric, arsenic, boric, silicic, tungstic, molybdic, and titanic acid. With respect to the three last named, see par. 67.

Reactions with Zinc and Hydrochloric Acid after previous Decomposition.

67. A mixture of sodium carbonate and nitre is added to the finely powdered assay, the mass is moistened slightly, and placed in a little spiral from about 2 to

3 mm. in diameter formed at the end of a very fine platinum wire. After fusing for a short time, the glowing mass is thrown off into a porcelain dish, and digested with a little water in a test tube. Afterwards a few drops of hydrochloric or sulphuric acid are added, and a strip of zinc is brought into the solution. By the reducing action of the nascent hydrogen formed, various colours are produced as exhibited in the following list ;

Molybdenum trioxide;	blue, then green, finally blackish-brown.
Tungsten trioxide ;	blue, then copper-red.
Vanadium pentoxide ;	blue, then green, finally violet.
Niobium pentoxide ;	blue ; often also brown (with strongly acid solution).
Chromium trioxide;	green.
Titanium dioxide;	violet.

APPENDIX TO CHAPTER II.

FLAME REACTIONS.

68. Bunsen[1] has shown that almost all reactions which can be performed by means of the blowpipe can be accomplished in the non-luminous flame of the gas-burner invented by himself. This burner, the upper part of which is shown in Fig. 17, is furnished with a hoop near the bottom for closing and opening the air-holes there situated, and a conical chimney above, of such a size that the flame may burn quite steadily. This flame, also shown in the figure, consists of the dark cone, *aba*, the flame mantle, *adac*, and the luminous point *bc*, not seen when the air-holes are fully open, but obtained on closing these holes up to a certain point. The following six points in the flame are used in the reactions.

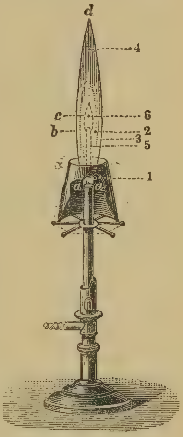

Fig. 17.

(1) *The base of the flame* at 1, where the lowest temperature exists, is specially employed to heat mixtures so as to obtain the flame-coloration due to the most volatile only.

(2) *The zone of fusion* at 2, constitutes the hottest part of the flame, and hence it is used in testing the fusibility and volatility, &c. of substances.

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[1] *Ann. Chem. Pharm.*, cxxxviii. 257. *Phil. Mag.*, [4] xxxii. 81.

(3) *The lower oxidizing flame* at 3, in the outer margin of the zone of fusion, is especially suitable for the oxidation of substances dissolved in beads of fused salts.

(4) *The upper oxidizing flame* at 4, is available for the roasting and oxidation of all substances which do not require an excessively high temperature. This acts most powerfully when the air-holes are quite open.

(5) *The lower reducing flame* at 5, on the inner edge of the mantle, next to the dark central cone. The reducing action of this part is not of the strongest; but it is specially available for reductions on charcoal, and in beads of fused salts.

(6) *The upper reducing flame* at 6, is formed above the dark cone when the admission of air is lessened by the gradual closing of the air-holes. If the luminous point is made too large soot is deposited on the objects placed within it; this ought never to occur. This part is especially available for reducing metals when it is desired to collect them in the form of films.

69. The following materials are used as assay supports:

(1) *Platinum wire;* this must scarcely exceed the thickness of a horse-hair, and one decimeter in length of the wire should not weigh more than 0·034 grm. It serves for investigations on fusibility, volatility, and flame-coloration, and also for examinations with borax, microcosmic salt and sodium carbonate.

(2) *Asbestos fibre* is used in place of platinum wire when the latter would be attacked by the substance under examination; the threads must not be more than one quarter the thickness of a lucifer match. In taking up the substance the asbestos is slightly moistened.

(3) *Charcoal splinter*, which serves as a substitute for

charcoal, is prepared by breaking off the head of a lucifer match and smearing over the rest of the match with a crystal of sodium carbonate partially fused by holding it near to the flame; the match is then held in the flame and slowly rotated. A charcoal splinter is thus obtained which is partially protected from burning by its coating of fused sodium carbonate.

(4) *Glass tubes*, about 3 mm. wide, 30 mm. long, and closed at one end.

When substances have to be held a long time in the reducing flame, it is convenient to use a Bunsen's stand, Fig. 18, which is provided with horizontal clips and arms, moveable, horizontally and vertically, on the vertical support. The arms carry small glass tubes supporting platinum wire or asbestos fibre, and the clips are used for holding test-tubes.

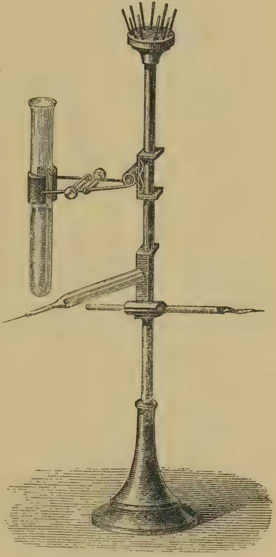
FIG. 18.

70. In addition to the reagents described in par. 5, the following are employed in the Bunsen flame reactions:

Stannous chloride solution, which should be kept in a well-stoppered bottle, in contact with a little metallic tin, to prevent the formation of stannic chloride which is useless for the purpose required. Stannous chloride is a strong reducing agent and serves for distinguishing films and to detect gold, molybdenum, tungsten, &c.

Caustic soda solution also serves for distinguishing films, and is further employed in testing for cobalt, nickel, tin, &c.

Silver nitrate, in perfectly neutral solution, serves for distinguishing films and in the detection of chromium and vanadium.

Fuming hydriodic acid, which, together with phosphorous acid, is formed by the action of moist air on phosphorous triiodide. For the preparation of the phosphorous iodide eight parts of iodine are added to one part of phosphorus in a test tube filled with carbon dioxide, and after the ignition has ceased the mass is heated to fusion. The tube is then carefully closed, and when the mass has solidified, it is placed in a shallow, wide-necked, well-stoppered glass bottle. To use the reagent a film produced on the outside of a porcelain dish is held over the mouth of the bottle, when, by the action of the gaseous hydriodic acid, iodine compounds are formed. If the reagent ceases to fume, some dry phosphoric acid is added.

The iodine compounds can also be produced by burning iodine tincture (solution of iodine in alcohol) on asbestos and holding the film over the flame. By this treatment the film sometimes receives a brown coloration, which, however, can be easily removed by warming gently.

Ammonia and *Ammonium sulphide* are employed in various tests, especially in the examination of films.

Bromine, preserved in a wide-necked, well-stoppered bottle, is applied by holding substances in the vapour evolved from it. Bromine vapour in the presence of water acts as an oxidizing agent.

Potassium ferrocyanide solution serves for the detection of iron, copper, and molybdenum.

Lead acetate (sugar of lead) is used for the detection of chromium.

Bismuth nitrate serves for the detection of tin.

Acetic acid is used in testing for chromium, vanadium, manganese, and uranium.

Mercuric cyanide serves for the detection of palladium, and is used but rarely.

Aqua-regia, a mixture of hydrochloric and nitric acids, is employed in testing for gold, platinum, &c.

Only very small quantities of the substance to be examined are employed. Decrepitating substances are ground to the finest powder and taken up on a small piece of moistened filter paper about a square centimeter in size. When this paper is carefully burnt between two rings of fine platinum wire, the assay remains behind as a compact crust which can then be treated in the flame without any difficulty.

METHOD OF EXAMINATION.

A. Behaviour on Heating.

71. On heating the substance the following appearances may be looked for :

(1) Whether the substance becomes *luminous* when brought into the hottest part of the flame.

(2) Whether the substance *fuses*, and whether at a higher or a lower temperature. It should be here noted whether the assay intumesces, changes colour, decreases in volume, or becomes transparent after cooling.

(3) Whether the substance *volatilizes*, and emits an odour.

(4) Whether the substance *colours the flame*. Flame-colouring substances when brought into the upper reducing flame produce a coloration in the upper oxidizing flame. Mixtures of flame-colouring substances are first held in the lowest and coldest part of the flame so that the more easily volatile constituents are first vaporized.

B. Oxidation and Reduction.

72. (1) **Beads.** Oxidation and reduction in beads are effected by holding the bead, supported on platinum wire, in the lower oxidizing or lower reducing flame respectively.

(2) **Reduction in small glass tubes.** The perfectly dry substance is heated with sodium carbonate and carbon (soot from oil of turpentine) or with metallic sodium or magnesium in a thin tube closed at one end, about 3 mm. wide and 3 cm. long. The sodium is wiped free from petroleum with filter paper, rolled between the fingers to a small cylinder, and then placed in the midst of the substance within the tube. Magnesium is employed in the form of small pieces of wire. The small tube is then heated up to the fusing point of the glass, when the mass usually becomes incandescent. After cooling, the tube is crushed in order to apply further tests to the contents.

(3) **Reduction on charcoal splinter.** The substance in powder is made into a paste with a drop obtained by fusing a crystal of sodium carbonate, and the pasty mass, which must be about the size of a mustard seed, is first fused in the lower oxidizing flame, and afterwards it is brought into the hottest part of the lower reducing flame lying just opposite. After reduction has taken place, known by the violent effervescence of the mass, the assay is allowed to cool by lowering it into the dark kernel of the flame. The end of the splinter is then cut off, ground down with a few drops of water in an agate mortar, and the product is examined in the usual way after washing off the charcoal.

C. Films on Porcelain.

73. Those volatile elements which are reduced by hydrogen or carbon can be deposited from their com-

pounds as films on porcelain either in the elementary state or as oxides. Such deposits can be easily converted into iodides, sulphides, and other compounds, exhibiting characteristic appearances. The deposit consists in the centre of a thick incrustation, which gradually thins out on all sides until the merest tinge exists; it is therefore necessary to distinguish between the "thick" and "thin" parts of the deposit. These reactions are so delicate that in many cases 0·1 to 1 mgr. is sufficient to produce them.

The following films are produced:

(a) *Metallic films.* These are obtained by holding with one hand a particle of the substance on an asbestos fibre in the upper reducing flame, which must not be too large, whilst the other hand supports a thin porcelain dish from 10 to 12 cm. in diameter, filled with water, close over the assay in the upper reducing flame. The metal separates out as a black film which may be either dull or lustrous as the case may be. On adding a little dilute nitric acid, containing about 20 per cent. of acid, to these films, the following reactions occur:

Film dissolves immediately	Lead. Cadmium. Zinc. Indium.
Film dissolves slowly	Bismuth. Mercury. Thallium.
Film is insoluble	Tellurium. Selenium. Antimony. Arsenic.

(b) *Oxide films.* The porcelain dish is now held in the upper oxidizing flame, the operation in other respects being conducted as in the production of the metallic film.

The oxide film is tested: (*a*) with stannous chloride alone; (*b*) with stannous chloride and subsequent addition of caustic soda; (*c*) with neutral silver nitrate solution followed by a current of ammoniacal air.[1]

(c) *Iodide films.* These are obtained by breathing upon oxide films and then holding them over a vessel evolving fumes of hydriodic acid. The iodide film is further tested (*a*) by breathing moist air on to it, and (*b*) by blowing ammonia fumes upon it.[2]

(d) *Sulphide films* are obtained from the iodide films by directing upon them a stream of air charged with ammonium sulphide, and removing the excess of ammonium sulphide by gently warming the porcelain vessel. The film is tested as to its solubility (*a*) in water by breathing upon it or adding a drop of water; (*b*) in ammonium sulphide, also by blowing or dropping.

REACTIONS OF THE ELEMENTS.

74. The substances which can be recognized by their flame reactions are arranged in the following groups according to their behaviour under oxidation and reduction:

(A) **Reducible to metal and deposited as film on porcelain.**

(B) **Reducible to the metallic state but giving no film.**

(C) **Elements most easily detected by the reactions of their compounds.**

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[1] The ammonia fumes are best applied by using a small wash-bottle containing ammonia solution, in which the blowing-tube dips under the liquid whilst the jet tube begins just beneath the cork.

[2] The iodine films described in par. 63, including those of non-volatile elements, can be produced on the porcelain dish by bringing the assay, mixed with sulphur iodide, on asbestos in the upper oxidizing flame.

75. GENERAL VIEW OF FLAME REACTIONS.

The numbers refer to the paragraphs in which the reactions are more fully described.

METHOD APPLIED.	RESULT OBTAINED.	INFERENCE.
I. It is sought to produce a metallic film on porcelain.	A film is produced which is tested as to its solubility in dilute nitric acid (about 20 % acid).	Scarcely at all soluble; Te (76), Se (77), Sb (78), As (79). Difficultly soluble; Bi (80), Hg (81), Tl (82). Readily soluble; Pb (83), Cd (84), Zn (85), In (86).
II. The substance is heated on charcoal splinter with Na_2Co_3.	(*a*) A grey powder. (*b*) A metallic bead.	Magnetic; Fe (87), Ni (88), Co (89). Non-magnetic; Pd (90), Pt (91), Ir (92), Rh (93). Cu (97), Sn (98), Ag (96), Au (95).
III. The substance is fused with Na_2CO_3 and KNO_3 in a platinum spiral.	(*a*) A whitish colourless melt. (*b*) A yellow melt. (*c*) A green melt.	Mb (99), W (100), Ti, (101), Ta, Nb, Si (106). Cr (102), Y (103). Mn (104).
IV. Special tests for the detection of U (105), P (107), S (108).		
V. Flame coloration.	Na (51), Sr (55), Li (52), Ba (53), K (50), Ca (54).	

(A) ELEMENTS WHOSE COMPOUNDS ARE REDUCED

The reactions of these bodies are

	Element Film.	Oxide Film.	Oxide Film with $SnCl_2$.	Oxide Film with $SnCl_2$ and NaHO.	Oxide Film with $AgNO_3$ and NH_4HO.	Iodide Film.
76 Te.	Black, thin film brown	White.	Black.	Black.	White to yellowish.	Brown; disappears for a time on breathing.
77 Se.	Cherry-red, thin film brick-red.	White.	Brick-red.	Black.	White.	Brown; does not wholly disappear on breathing.
78 Sb.	Black, thin film brown.	White.	White.	White.	Black, insoluble in NH_4HO.	Orange-red to yellow; disappears on breathing.
79 As.	Black, thin film brown.	White.	White.	White.	Lemon-yellow or brownish red; sol. in NH_4HO.	Orange-yellow; disappears for a time on breathing.
80 Bi.	Black, thin film brownish black.	Yellowish white.	White.	Black.	White.	Bluish brown, thin parts pink; disappears for a time on breathing.
81 Hg.	Grey non-coherent thin film.	...	...	...	...	Carmine-coloured and lemon-yellow; does not disappear on breathing.
82 Tl.	Black, thin film brown.	White.	White.	White.	White.	Lemon-yellow; does not disappear on breathing.
83 Pb.	Black, thin film brown.	Light ochre yellow.	White.	White.	White.	Orange-yellow to lemon colour; does not disappear on breathing.
84 Cd.	Black, thin film brown.	Black to brown, thin film white	White.	White.	White; turns bluish-black in the thin parts.	White.
85 Zn.	Black, thin film brown.	White.	White.	White.	White.	White.
86 In.	Black, thin film brown.	Yellowish white.	White.	White.	White.	Yellowish-white.

TO METAL, FORMING A FILM ON PORCELAIN.

collected in the following table.

Iodide Film with NH_3.	Sulphide Film.	Sulphide Film with $(NH_4)_2S$.	Flame Coloration.	
Disappears altogether.	Black to blackish brown.	Disappears for a time.	Upper reducing flame pale blue; upper oxidizing flame green. No odour.	Element film scarcely soluble in dilute nitric acid.
Does not disappear.	Yellow to orange.	Orange; disappears for a time.	Cornflower blue. Odour of rotten horse-radish.	
Disappears altogether.	Orange.	Disappears for a time.	Upper reducing flame pale greenish. No odour.	
Disappears altogether.	Lemon-yellow.	Disappears for a time.	Upper reducing flame pale blue. Odour of garlic.	
Pink to orange yellow; becomes chestnut-brown in air current.	Burnt-umber, thin parts coffee brown.	Does not disappear.	Bluish; not characteristic.	Element film soluble with difficulty in dilute nitric acid.
Disappears for a time.	Black.	Does not disappear.	...	
Does not disappear.	Black, thin film bluish-grey.	Does not disappear.	Light grass-green.	
Disappears for a time.	Brown-red to black.	Does not disappear.	Light-blue.	Element film readily soluble in dilute nitric acid.
White.	Lemon-yellow.	Does not disappear.	...	
White.	White.	Does not disappear.	...	
Yellowish white.	White.	Does not disappear.	Intense indigo-blue.	

(B) ELEMENTS WHOSE COMPOUNDS ARE REDUCED TO THE METALLIC STATE, BUT GIVE NO FILM.

1. METALS NOT FUSED TO A BEAD AFTER REDUCTION.

a. Magnetic Metals.

87. **Iron compounds.** *Reduction on charcoal splinter.* No metallic bead or glistening spangles; after grinding the reduced mass in an agate mortar, the particles of iron may be collected as a non-lustrous brush on the end of a magnet. The particles on paper give yellow stains when moistened with a drop of aqua-regia, and warmed over the flame; the yellow stains become deep blue on moistening with potassium ferrocyanide. The paper should be previously tested for iron.

Borax bead. Oxidizing flame; *hot*, yellow to brownish-red; *cold*, yellow to brownish-yellow. Reducing flame, bottle-green.

88. **Nickel compounds.** *Reduction on charcoal splinter.* White, glistening, ductile, metallic spangles which form a brush on the magnet. The metal moistened on paper with nitric acid gives a green solution, which on treatment with soda, exposure to bromine vapour, and subsequent addition of caustic soda, gives a black stain of nickel peroxide.

Borax bead. Oxidizing flame, dirty violet; upper reducing flame, grey from the separation of metallic nickel, which often unites to form a silver-white nickel sponge, whilst the bead becomes colourless.

89. Cobalt compounds. *Reduction on charcoal splinter.* White, glistening, ductile, metallic spangles, which form a brush on the magnet. The metal when moistened on paper with nitric acid gives a red solution, which, on addition of a little hydrochloric acid, and drying, gives a green stain; on moistening, the green stain again disappears. On treatment with caustic soda solution and bromine vapour, a brownish-black spot of peroxide is obtained as in the case of nickel.

Borax bead. In both flames deep blue.

b. Non-Magnetic Metals.

90. Palladium compounds. *On platinum wire with sodium carbonate.* In the upper oxidizing flame palladium compounds are reduced to a grey mass like platinum sponge which yields silver-white, glistening, ductile metallic spangles, on grinding in an agate mortar. After washing and drying, the scales dissolve in nitric acid with a reddish-brown colour. On adding a drop of mercuric cyanide, and blowing ammoniacal air upon the solution, a white flocculent precipitate is obtained which dissolves on adding a little ammonia solution.

91. Platinum compounds. *On platinum wire with sodium carbonate.* In the upper oxidizing flame platinum compounds are reduced to a grey spongy mass which yields silver-white, glistening, ductile, metallic spangles, on grinding in an agate mortar. These are not soluble in nitric or hydrochloric acid, but dissolve readily in aqua-regia. If the platinum is pure, the solution has a light-yellow colour; if palladium, rhodium, or iridium is present, the solution is brownish-yellow. The solution gives no white flocculent precipitate with mercuric cyanide and ammoniacal air, but a light-yellow crystalline precipitate of ammonium platinum chloride falls down.

92. Iridium compounds. *On platinum wire with sodium carbonate.* In the upper oxidizing flame iridium compounds are reduced to a metallic powder, which is neither lustrous nor ductile when rubbed in the agate mortar. The powder is perfectly insoluble, not only in nitric and hydrochloric acids, but also in aqua regia.

93. Rhodium compounds. These can only be distinguished from iridium compounds by fusing the reduced metallic powder with hydrogen potassium sulphate, when the metal is partially oxidized, and a rose-red solution is obtained.

94. Osmium compounds. In the oxidizing flame these give volatile osmium tetroxide, possessing a chlorine-like odour, and attacking the eyes powerfully.

2. *METALS FUSED TO A BEAD AFTER REDUCTION.*

95. Gold compounds. *Reduction on charcoal splinter with sodium carbonate.* A shining yellow ductile metallic bead is obtained, giving gold-like spangles in the mortar. These are insoluble in hydrochloric or nitric acid, but dissolve in aqua-regia to a light-yellow solution, which, when taken up on filter paper and moistened with stannous chloride, yields "purple of Cassius."

96. Silver compounds. *Reduction on charcoal splinter with sodium carbonate.* A white ductile bead is obtained which dissolves in nitric acid on warming gently. The solution gives with hydrochloric acid a curdy white precipitate, insoluble in nitric acid, but soluble in ammonia.

97. Copper compounds. *Reduction on charcoal splinter with sodium carbonate.* A copper-red ductile bead is obtained which dissolves to a blue solution in nitric acid. If to a little of the solution, taken up on filter paper, a drop of potassium ferrocyanide be added, a brown stain is obtained.

On platinum wire with borax. A blue bead is obtained which becomes reddish-brown in the lower reducing flame on the addition of a little stannous oxide, from the formation of cuprous oxide. By alternate oxidation and reduction, a transparent ruby-red bead is formed ; this is best obtained when the reduced bead is allowed to oxidize slowly.

98. Tin compounds. *On charcoal splinter.* White lustrous ductile bead, soluble in hydrochloric acid, and converted by nitric acid into insoluble stannic oxide. The solution gives a black precipitate with bismuth nitrate and excess of caustic soda.

(C) ELEMENTS MOST EASILY DETECTED BY THE REACTIONS OF THEIR COMPOUNDS.

a. Metallic Substances.

99. Molybdenum compounds. *On charcoal splinter.* Reduced with difficulty to a grey powder.

Borax bead (little characteristic). In the oxidizing flame the bead is at first colourless ; as the point of saturation is approached a bluish enamel is obtained. In the reducing flame the bead becomes dark from the separation of molybdenum oxide.

Special Reactions. The finely-powdered substance is mixed to a paste with sodium carbonate obtained from a fused crystal of the substance; the mixture is fused, on a platinum spiral of about 2 to 3 mm. in diameter, in the lamp flame, and the white-hot fused mass is struck off, and dissolved in a few drops of warm water. The supernatant clear liquid is taken up on a strip of filter paper, with which the following reactions are obtained: hydrochloric acid, and then potassium ferrocyanide, give a reddish brown stain; stannous chloride, added gradually, produces either directly or on warming a blue colour; ammonium sulphide gives a brown colour, and after addition of hydrochloric acid, a brown precipitate is produced, whilst the paper around the precipitate is often coloured blue.

100. **Tungsten compounds.** These compounds are fused on a platinum spiral in the same way as the molybdenum compounds, and the aqueous solution is taken up on filter paper. Hydrochloric acid and potassium ferrocyanide produce no coloration. Ammonium sulphide alone or with the addition of hydrochloric acid gives no precipitate. The paper, however, becomes blue or greenish-coloured in the latter case, especially on warming.

101. **Titanium compounds.** *Microcosmic bead.* Oxidizing flame, colourless; reducing flame, faint amethyst colour. On addition of a little ferrous sulphate, the bead in the lower reducing flame assumes the peculiar red colour of venous blood.

With sodium carbonate on platinum wire. Titanium compounds dissolve, and form beads colourless and transparent whilst hot, and opaque when cold. The hot bead moistened with stannous chloride, and treated in the lower reducing flame, becomes grey-coloured, and dissolves in hydrochloric acid on warming with a faint amethyst colour.

Tantalum and niobium compounds. These behave like the titanium compounds.

102. **Chromium compounds.** *On the platinum spiral with sodium carbonate.* Fused with repeated additions of potassium nitrate, chromium compounds give a light-yellow mass, which gives a light-yellow solution with water. This solution separated from the residue, acidified with acetic acid, and taken up on filter paper, gives a yellow precipitate with lead acetate, and a reddish-brown one with silver nitrate solution. On addition of ammonium sulphide or stannous chloride, or by evaporation with aqua-regia, the colour of the solution changes from yellow to green.

Borax bead. In both flames the bead is emerald green.

103. **Vanadium compounds.** *Platinum spiral with sodium carbonate and nitre.* A yellowish fused mass is obtained. When dissolved and acidified with acetic acid silver nitrate gives a yellow precipitate. The solution evaporated with aqua-regia does not give a green liquid, but a yellow or yellowish-brown one, which by the addition of stannous chloride becomes blue.

Borax bead. Oxidizing flame, greenish yellow; reducing flame, green.

104. **Manganese compounds.** *Borax bead.* Oxidizing flame, amethyst colour; reducing flame, colourless.

Platinum spiral, with sodium carbonate and nitre. A green mass is obtained, giving a green solution with water, which, on acidifying with acetic acid, becomes red, and then often turns colourless, with separation of brown flakes.

105. Uranium compounds. *Borax bead.* Oxidizing flame, yellow; reducing flame, green. The uranium and iron colorations are very similar, but the hot uranium bead is distinguished by emitting a bluish-green light.

Microcosmic bead. Reducing flame, beautiful green; whilst iron gives a bead reddish to colourless in the cold.

Platinum spiral with hydrogen potassium sulphate. The insoluble uranium compounds are thus decomposed. The fused mass is powdered with a little sodium carbonate, moistened, and absorbed by filter paper; after moistening with acetic acid, a brown spot is produced by potassium ferrocyanide.

b. Non-Metallic Substances.

106. Silicon compounds. *Microcosmic bead.* Small splinters of silicates yield an infusible skeleton of silica, which floats about in the bead.

Sodium carbonate bead. In the oxidizing flame a clear bead is formed with effervescence; gelatinous silica separates when the bead is carefully evaporated with water and acetic acid.

107. Phosphorus compounds. The substance is heated with magnesium wire in the small tube closed at one end, the mass becoming incandescent. The tube is crushed, and the contents are moistened with water, when the characteristic odour of hydrogen phosphide is perceptible. In the place of magnesium, sodium may be employed in the reaction.

108. Sulphur compounds. *On charcoal splinter with sodium carbonate.* Heated in the lower reducing flame a fused mass is obtained, which gives a black stain when moistened on a piece of silver. As selenium and tellurium compounds give the same reaction, it is necessary to ascertain the absence of these by the film test (pars. 76 and 77).

Sulphides are readily recognized by the odour of sulphur dioxide given off when they are heated.

CHAPTER III.

SPECIAL EXAMINATION FOR CERTAIN ELEMENTS IN COMBINATION.

109. The reactions described in the previous chapters suffice for the detection of the more simple chemical compounds. In the case, however, of the more complex compounds which are met with in practice, the indications thus obtained are scarcely sufficiently characteristic, as the reactions of the various elements contained in the substance under examination are in many cases either modified or obscured by the other constituents present.

For example, the mineral bournonite which, in addition to lead, contains antimony, copper and sulphur, gives reactions quite different from those exhibited by the pure lead compounds. The latter yield an incrustation which is lemon-yellow when hot and sulphur-yellow when cold, together with a malleable metallic bead. Bournonite, on the other hand, gives first a white incrustation of antimony oxide, soon accompanied by lead antimonate, lead sulphate and lead oxide, so that the incrustation nearest the assay has a dark-yellow colour very closely resembling a bismuth incrustation. The bead which remains is usually brittle and black, and yields with borax in the oxidizing flame a pearl which is green when hot and blue on cooling; in the reducing flame this does not always become brown and opaque as might be expected, but is frequently rendered grey by the antimony contained in the bead.

In such instances it is possible frequently to detect many if not all the constituents of the mixture in the ordinary way by careful observation of its various reactions, and by comparison of the results with those obtained in the examination of other substances. Very often, however, the course of investigation must be considerably modified, and in some cases indeed it is necessary to make use of the wet method to clear up doubtful points.

The present chapter contains a description of the mode of examination in those cases in which a special procedure is necessary for the detection of a body when occurring along with other substances. Here are given also the most important reactions of those elements which are not sufficiently characterized in the ordinary blowpipe course. The substances are arranged alphabetically for convenience of reference.

110. **Ammonium.** The substance is mixed with carbonate of soda or caustic potash, and heated in a glass tube closed at one end. Ammonia is evolved, and is recognized by its odour, and by the white fumes produced when a glass rod moistened with hydrochloric acid is held near to the tube.

It should, however, not be overlooked that organic compounds containing nitrogen also yield ammonia as a decomposition-product by this treatment.

Antimony. For the reactions of antimony and its compounds, see pars. 11, 16, 25, 62, 63, 78, and No. 16 in the table at the end of the book.

111. To detect antimony in presence of other volatile

metals, the incrustation on charcoal is moistened with a drop of hydriodic acid, which is prepared by passing a stream of hydrogen sulphide through water holding powdered iodine in suspension. By repeated heating, the antimony film becomes a beautiful red colour, the bismuth film brown, the lead film light yellow, and the cadmium film white. (Haanel. See also par. 63.)

112. In presence of *lead* or *bismuth*, antimony cannot be detected by its incrustation alone. In this case the assay [No. 45 or 81] is heated on charcoal with fused boric acid, which dissolves the lead and bismuth oxides, whilst the antimony oxide incrusts the charcoal. The temperature ought not to be too high.

113. Antimony when combined with *copper* is separated with so much difficulty that hardly any incrustation is obtained. Such a mixture [No. 82] is treated with microcosmic salt until a part of the antimony passes into the glass; this is then separated from the metallic bead and heated with a little tin on a piece of charcoal in the reducing flame. In presence of antimony the glass becomes grey or black [No. 16 of end table]. Should bismuth, which behaves similarly to antimony, be likewise present, examination in the wet way must be resorted to.

114. *Oxides of antimony, tin, and copper.* The substance is treated with a mixture of sodium carbonate and borax in the reducing flame; the metallic bead after separation from the glass is then fused with from 3 to 4 times its volume of assay-lead together with some fused boric acid in the reducing flame. The copper remains behind in the metallic state, the tin passes into the slag, and the antimony incrusts the charcoal.

115. *Antimony sulphide and lead sulphide.* Although the antimony sulphide exhibits the reaction described in par. 16, yet in consequence of the presence of the lead sulphide, only a slight sublimate of antimony oxide is formed. The residue forms a white powder consisting of antimony tetroxide, sulphate of lead and antimonate of lead. For the detection of antimony proceed as in par. 154.

Antimony sulphide and sulphide of lead or bismuth. On charcoal in the reducing flame a yellow incrustation of lead oxide or bismuth oxide is formed near to the assay, and further away a white one of antimony oxide mixed with lead or bismuth sulphate. The antimony is confirmed according to par. 154.

116. In order to detect a small quantity of *antimony sulphide* in presence of *arsenic sulphide*, Plattner recommends the following method. The assay [No. 23] is gently heated in a tube closed at one end whereby the arsenic sulphide is volatilized and the greater part of the antimony sulphide remains as a black powder at the bottom of the tube. The end of the tube is then broken off and the substance is heated in an open tube, when the characteristic antimony reaction is obtained.

Arsenic. The reactions of arsenic and its compounds are given in pars. 11, 15, 34, 62, 63, and 79.

117. All arsenides give in the open tube a sublimate of arsenic trioxide (see par. 15), and most of them on charcoal in the reducing flame develop the characteristic odour of arsenic[1] (par. 34) [No. 73]. When from the presence of nickel or cobalt, the odour is not produced, it can in most cases be obtained by fusing with assay-lead in the oxidizing flame.

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[1] According to Vogel the arsenic odour is best obtained by making the assay into a paste with charcoal powder, and dilute shellac solution ; small pencils are made of the paste and these are then burnt.

118. *Arsenic sulphide* gives off sulphur dioxide on heating in the open tube and yields a sublimate of arsenic trioxide. To detect arsenic with certainty in any combination with sulphur, the powdered assay [No. 76] is heated with six times its volume of a mixture of equal parts of potassium cyanide and sodium carbonate. A glass tube with a bulb at one end is used, and the heat is applied gently at first, but finally increased to redness. An arsenic mirror forms on the cold part of the tube. To succeed with this characteristic experiment it is necessary that the substance and reagents shall be perfectly dry. Hence if moisture appears on first heating the tube, it must be carefully removed by means of a roll of filter paper.

119. When *arsenic sulphide* is heated on charcoal, it may happen that the whole of the arsenic, especially if present in small quantity only, is driven off in combination with the sulphur. This is prevented by mixing such compounds [No. 23] with from 3 to 4 parts of normal potassium oxalate or potassium cyanide, and heating in the reducing flame. Potassium sulphide is formed, and the arsenic, when not combined with nickel or cobalt, is expelled with its characteristic odour.

120. According to Berzelius, a very minute quantity of *arsenic trioxide* can be easily detected in the following way. A grain of the substance is placed at the end of a drawn-out closed tube, Fig. 19, and a splinter of freshly ignited charcoal is then pushed in just in front of the assay; the charcoal is first heated, and the heat is then extended to the assay, the whole being brought up to

redness. The arsenic trioxide is reduced to metal as its vapour passes over the ignited charcoal, and a mirror is formed above the heated portion of the tube. If the tube be broken between *a* and *b* and heated, the arsenic odour is perceptible [No. 41].

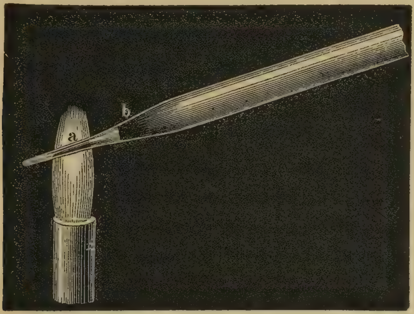

FIG. 19.

121. To detect arsenic in *arsenates* and *arsenites*, the treatment with sodium carbonate, or with a mixture of this and potassium cyanide, is in most cases sufficient (par. 118). When, however, very small quantities of these acids are combined with an easily reducible metal, the wet method must be resorted to.

Bismuth. For the reactions of bismuth and its compounds, see pars. 12, 17, 26, 62, 63, 80, and No. 18 in the table at the end of the book.

122. In alloys, as it generally occurs in nature and in metallurgical products, bismuth is usually detected by its incrustation. When combined with sulphur, the yellow incrustation is surrounded by a white one of bismuth sulphate. The formation of the latter can, however, be prevented by the addition of sodium carbonate.

To detect bismuth when present with other incrustation-forming metals, antimony excepted, the incrustation is scraped from the charcoal, and dissolved in microcosmic salt on platinum wire in the oxidizing flame ; the bead is then struck off the wire and reduced on charcoal with a little tin, when the grey or black colour of the bead indicates bismuth. Antimony gives a similar reaction. If this be present, the assay must be previously heated in the oxidizing flame until all the antimony has been expelled. According to Kobell, any bismuth compound treated on a large piece of charcoal with a mixture of equal parts of potassium iodide and sulphur (or with potassium iodide alone if the substance contains sulphur), yields a very characteristic beautiful red incrustation at some distance from the assay. Substances containing lead, when similarly treated, give a deep yellow incrustation, which does not interfere with the bismuth reaction. (See also par. 63.)

123. Cornwall has modified Kobell's method for the detection of bismuth in presence of antimony and lead in the following way: The substance, mixed with an equal volume of sulphur, is placed in a deep hole in charcoal, and heated for a short time with the blue flame. The fused sulphide formed is then brought on to a flat part of the charcoal, and exposed alternately to the oxidizing and reducing flames, until antimony fumes cease to be evolved, and a blue flame due to lead appears. To the pulverized residue is then added an equal quantity of a mixture of one part of potassium iodide and five parts of sulphur. The whole is heated over a gas- or spirit-lamp in an open tube, from 10 to 12 cm. long, and 10 mm. wide. A distinct sublimate of red bismuth iodide forms about 10 mm. above the yellow lead iodide sublimate. An iodine sublimate which may form further away from the assay must not be mistaken for the bismuth sublimate.

124. **Boron.** To obtain the yellowish-green colour which boric acid imparts to the blowpipe flame, the salt [No. 26] is finely powdered, moistened with a drop of concentrated sulphuric acid, and brought into the flame on a platinum wire.

The flame-coloration is still better obtained by mixing the finely powdered substance with 4 parts of hydrogen potassium sulphate, and 1 part of calcium fluoride (Turner). The mixture is moistened with a drop of water and brought into the flame on a platinum loop; on fusion boron fluoride is formed which colours the flame a pure green. As the coloration is only momentary, careful observation is required.

Another reliable reaction has been proposed by Iles. The finely powdered material is moistened on platinum foil with sulphuric acid, the excess of acid is volatilized by warming, and the powder is mixed to a paste with glycerine. This is then brought by means of a platinum wire into the flame, when the latter acquires a green colour.

The presence of copper interferes with the fluoride test owing to the formation of copper fluoride which gives to the flame a strong green colour. The glycerine test can still be applied, and if sufficient copper is present to produce a green flame before the addition of glycerine a little sodium carbonate added to the paste will cause a yellow sodium flame which masks the green coloration due to copper, but not that due to boron (Hutchings).

125. The following is a very sensitive reaction for

borates of the alkalis and alkaline earths. The assay is dissolved in dilute hydrochloric acid, and a piece of turmeric paper is partially dipped into the solution; after drying at 100° C. that portion of the paper with which the liquid has come into contact assumes a brownish-red colour in presence of boric acid. This colour must not be confounded with the dark-brown produced by concentrated hydrochloric acid on turmeric paper.

The red colour of the turmeric paper, on moistening with the solution of an alkali, is changed to bluish- or greenish-black.

Bromine. For the behaviour of bromine compounds towards hydrogen potassium sulphate, see par. 64.

126. If a bromine compound be added to a microcosmic bead containing copper oxide, and this be then heated with the tip of the blue flame, the latter becomes greenish-blue coloured, especially at the edge [No. 31]. After the volatilization of the bromine the green copper flame reappears. Chlorine behaves in a similar manner (see par. 128).

Cadmium. For the reactions of cadmium and its compounds, see pars. 11, 36, 62, 63, 84, and No. 19 of the table at the end of the book.

127. *Oxides of cadmium and zinc.* The powdered assay is mixed with sodium carbonate, and heated on charcoal in the reducing flame. There is first formed the brown incrustation of cadmium oxide, and afterwards that of the less volatile zinc oxide [No. 50].

Chlorine. The reaction of the chlorine compounds on charcoal is given in par. 40; that with hydrogen potassium sulphate in par. 64.

128. Copper oxide is dissolved in a microcosmic bead on platinum wire until the bead becomes almost opaque, a little of the powdered assay [No. 33] is placed on the bead, and the point of the blue flame is brought to bear upon it. In presence of chlorine the flame is coloured of an intense blue from the formation of copper chloride (par. 42). Minute quantities of chlorine can be detected by this reaction. Bromine behaves similarly.

129. When a chloride is gently heated with dry potassium chromate and concentrated sulphuric acid, dark brownish-red vapours of chlorochromic acid are evolved, which condense to drops of the same colour. Ammonia turns this liquid yellow.

Chromium. For the reactions of chromium and its compounds, see pars. 41, 60, 62, 66, 67, 102, and No. 21 of the table at the end of the book.

130. The reactions with borax and microcosmic salt are generally very characteristic; still the colours are often obscured in the presence of large quantities of iron, copper, or other strongly colouring substance. In such cases chromium, when not combined with silica, may be detected in the following way: The finely-powdered assay is mixed with double its quantity of a mixture of equal parts of sodium carbonate and potassium nitrate, and fused in a platinum spoon or on a platinum spiral in a strong oxidizing flame. An alkaline chromate is formed, which is then dissolved in water, and boiled with an excess of acetic acid. A crystal of lead acetate brought into the solution produces a yellow precipitate of lead chromate, which may be collected on a filter, and further tested with borax and microcosmic salt. If, instead of lead, silver nitrate be added, a dark purple-red precipitate of silver chromate is produced.

131. *Silicates* which contain but little chromium together with iron or other strongly-colouring metallic oxide, are treated on charcoal with one part of sodium carbonate and half a part of borax in the oxidizing flame, until a clear glass is produced, which is pulverized and evaporated with hydrochloric acid in a porcelain capsule. The chlorides thus formed are dissolved in water, separated by filtration from the separated silica, the iron is oxidized by boiling with a few drops of nitric acid, and the basic chromium oxide together with other substances is precipitated by ammonia. The precipitate is collected on a filter, washed, and treated as before described with sodium carbonate and potassium nitrate.

Cobalt. For the reactions of cobalt and its compounds see pars. 41, 62, 63, 89, and No. 22 of the table at the end of the book. To detect cobalt in the presence of other metals, see also pars. 146, 147, and 152.

132. In examining metallic compounds for cobalt it is advisable to powder the substance finely, and to roast on charcoal, so as to remove arsenic and sulphur. Lead and bismuth when present yield under this treatment incrustations on the charcoal. The residue is heated with borax in the oxidizing flame. If it forms a glass which is not a pure blue, the presence of iron is indicated (see par. 146). In such a case, the glass is removed from the assay, and fresh quantities of borax are added until a pure blue colour appears. Nickel and copper are only taken up by the flux, when the cobalt present has been oxidized. For the detection of these metals the blue glass is separated from the bead, which is fused (in the oxidizing flame) with new portions of borax, until the glass becomes brown with nickel oxide. After this

glass has been removed, microcosmic salt is added, the oxidizing flame being still used, and a green bead is obtained in presence of copper, which, when cold, retains this colour, and by reduction on charcoal with a little tin becomes red and turbid [Nos. 74 and 75].

133. The above process can be modified so as to better separate nickel and copper by adding some assay-lead together with the borax, and treating in the reducing flame. Nickel and copper pass into the lead bead; the glass is examined on platinum wire for cobalt, whilst the lead bead is heated in the oxidizing flame with microcosmic salt, and becomes green when cold in the presence of nickel and copper. Nickel alone yields a yellow bead, whilst copper gives a blue bead which by reduction on charcoal with tin becomes red and turbid.

Copper. For the reactions of copper and its compounds, see pars. 24, 41, 56, 62, 63, 97, and No. 23 of the table at the end of the book.

134. Copper is readily recognized by the brown borax bead and the red microcosmic bead which result when beads produced in the oxidizing flame are heated on charcoal with tin in the reducing flame. By repeated oxidation and reduction, the borax bead becomes ruby-red, especially when the reduced bead is allowed to oxidize slowly.

135. To detect small quantities of copper when combined with *metals*, the assay [No. 24, 82 or 81] is heated on charcoal in the oxidizing flame to expel volatile constituents. Boric acid, which has been previously fused to a bead, is then added, and the whole is heated in a large reducing flame, which covers the assay. As soon as the bead assumes a metallic appearance, the point of

an oxidizing flame is applied, so as just to touch the glass without grazing the metallic bead. By this process lead, iron, cobalt, a portion of the nickel, and also the volatile elements not wholly expelled by the previous roasting, such as bismuth, antimony, and zinc, are converted into oxide and are either volatilized or are absorbed by the glass. The remaining bead is separated from the glass, dissolved in microcosmic salt on charcoal in the oxidizing flame, and reduced with tin in the reducing flame.

136. To detect copper in compounds containing much *nickel*, *cobalt*, *iron*, and *arsenic*, the assay is first treated with borax on charcoal in the reducing flame, in order to dissolve the greater part of the iron and cobalt. The remaining metallic bead is treated with assay-lead and boric acid as above. Arsenic is volatilized, and the residue of iron and cobalt, together with a part of the nickel, is absorbed by the boric acid. The metallic bead, separated from the glass, is dissolved in microcosmic salt under an oxidizing flame, when the presence of copper is indicated by the dark-green glass becoming light-green on cooling, this latter colour resulting from the yellow nickel and blue copper beads [No. 78].

To recognize copper in presence of *tin*, see par. 176.

137. If the copper is combined with *sulphur*, the assay is roasted on charcoal, and its behaviour with microcosmic salt examined. Should a black or grey bead result from the presence of antimony or bismuth, it is necessary to treat the assay after roasting with sodium carbonate, borax, and assay-lead on charcoal in the reducing flame; the separated metallic bead is then

strongly heated to remove the antimony, and afterwards boric acid is added, as in par. 135 [No. 72].

138. Cupriferous minerals often impart a green colour to the non-luminous flame, or when the metal is combined with chlorine, an azure-blue colour. If the reaction does not immediately appear, it may be frequently produced by powdering the assay and moistening with a drop of concentrated hydrochloric acid, evaporating to dryness, and rubbing the powder into a paste with water, which can then be brought into the flame on a platinum loop [No. 69].

139. **Fluorine.** If fluorine compounds be heated with four times their quantity of hydrogen potassium sulphate in a tube closed at one end, hydrofluoric acid is evolved, which turns moist Brazil-wood paper straw-yellow, and corrodes the glass all about the mixture. It is best to heat the mixture from above downwards, to prevent the contents of the tube from being ejected, and the corrosion is best seen after cleaning and drying the tube. Minerals in which hydrofluoric acid is combined with weak bases and with water at the same time, simply require heating in the glass tube to produce the reaction described [No. 56].

140. To detect very small quantities of fluorine in minerals, &c., the following method is used. A small bent piece of platinum foil is pushed into the end of an open glass tube, and on the foil is laid a mixture of the assay with calcined microcosmic salt, both finely powdered; the flame is now applied to the mixture so that the products of combustion pass through the tube. If the substance contains fluorine, hydrofluoric acid, possessing a peculiar pungent odour, is generated, the tube

is etched, and moist Brazil-wood paper is coloured yellow [No. 29].

141. **Gold.** For the reactions of gold and its compounds, see pars. 24, 30, 62, 95, and No. 26 of the table at the end of the book. An alloy of gold with volatile metals, such as mercury, antimony, and tellurium, needs only to be heated on charcoal in the oxidizing flame, in order to obtain a bead of gold which can be recognized by its physical properties. Lead is removed as described in par. 169.

A bead containing the infusible metals, such as platinum and iridium, is much less fusible than pure gold. Such mixtures can only be examined in the wet way.

142. When together with *copper*, whose presence can easily be ascertained by testing with microcosmic salt, gold is detected as follows. The alloy, a gold coin for example, is dissolved in assay-lead and the mass is cupelled. In this way the copper is removed. If the alloy contains *silver*, the resulting bead is treated with microcosmic salt on charcoal in the oxidizing flame. The silver is gradually oxidized and taken up by the glass, and the latter on cooling becomes opaline in consequence. To determine roughly the relative weights of the two metals, the bead is warmed with hydrochloric acid in a porcelain capsule. If the alloy contains up to 25 per cent. of gold, it becomes black, the silver dissolves gradually, and the gold remains as a black or brown spongy mass. If more than 25 per cent. of gold be present, the bead also becomes black, but the silver is not dissolved. When the metals are present in about equal proportion, no change takes place. If the gold is considerably in excess, this can be recognized readily by the yellow colour of the alloy.

143. **Iodine.** The reaction of iodine with hydrogen potassium sulphate (see par. 64) is very characteristic.

When added to a microcosmic bead containing copper oxide, the outer flame acquires a pure green colour [No. 32].

144. Iodine combined with silver or with alkalis can be detected in the presence of other halogens by mixing the powdered substance with bismuth sulphide (easily prepared by heating bismuth and sulphur together), and heating on a large piece of charcoal before the blowpipe flame. If iodine is present, a beautiful red incrustation of bismuth iodide is produced.

Iron. For the reactions of iron and its compounds, see pars. 12, 24, 41, 62, 87, and No. 29 of the table at the end of the book. To distinguish *protoxide* from *peroxide*, the substance is added to a borax bead containing copper. With peroxide the bead is coloured bluish-green, whilst with protoxide red streaks of cuprous oxide appear.

145. To detect iron along with *easily fusible metals*, such as lead, bismuth, antimony, tin or zinc, the substance is heated on charcoal with borax in the reducing flame. The easily reducible metals do not become oxidized and consequently are not absorbed by the glass. The glass is separated from the metallic bead, and is heated on a fresh piece of charcoal in the reducing flame, when it acquires the characteristic bottle-green colour produced by iron, and becomes vitriol-green on addition of tin.

146. In presence of *cobalt*, the bead is not green but blue in colour. In such case iron is sought for by heating the blue glass on platinum wire in the oxidizing flame sufficiently long to convert all the iron into peroxide. With very little iron present, the bead is green when hot,

and blue when cold; with more iron the bead is dark green when hot, and pure green when cold, this latter resulting from a mixture of the yellow iron and blue cobalt colours.

The residual metal on the charcoal after the treatment with borax (often only nickel and copper) is examined according to par. 135.

147. An admixture of *manganese* [Nos. 80 and 65] colours the borax bead in the oxidizing flame red to blood-red. By reduction with tin on charcoal the bead becomes vitriol-green. If *cobalt* is present along with *manganese* a dark-violet bead is produced in the outer flame, which in the reducing flame becomes green when hot, and blue on cooling.

148. To test for iron in *nickeliferous* substances, the assay is dissolved in borax in the oxidizing flame, and then heated on charcoal in the reducing flame. Metallic nickel separates out, and the iron remaining dissolved in the glass colours it green.

149. A substance containing *iron* and *copper* gives a green borax bead in the outer flame both before and after cooling; from this bead copper separates on charcoal under the reducing flame, and the glass is green from iron. If the amount of copper present is small, the assay is fused together with borax, sodium carbonate, and assay-lead, the metallic bead obtained heated with boric acid in the oxidizing flame, and copper sought for by the aid of microcosmic salt and tin.

150. If *iron* and *chromium* occur together, the colour of the glass affords no indication of the presence of iron. The substance is fused with sodium carbonate on charcoal in the reducing flame, the reduced iron is separated

from the slag by washing, and the latter is fused with potassium nitrate for the detection of chromium.

151. *Iron* and *uranium oxides* cannot be distinguished from one another in the dry way. To separate them the assay is fused with hydrogen potassium sulphate, extracted with water, and the solution treated with ammonium carbonate to precipitate the iron; the filtrate is acidified, boiled to expel carbon dioxide, and the yellow uranium oxide is precipitated by ammonia. Both products are then further examined [No. 66].

152. A substance containing *iron*, *nickel*, *cobalt*, *manganese*, and *copper* is fused with metallic arsenic or with potassium arsenate, and the mass is treated with borax in successive portions in the oxidizing flame. There results,

first, a yellowish-green colour from iron.
then, a blue ,, ,, cobalt.
,, a brown, ,, ,, nickel.
,, a green, ,, ,, copper.

Under the reducing flame, nickel and copper can be separated from the borax glass, whilst iron, cobalt, and manganese remain dissolved, and are looked for according to par. 147.

Lead. For the reactions of lead and its compounds, see pars. 12, 27, 62, 63, 83, and No. 31 of the table at the end of the book.

153. An alloy of *lead* and *zinc* [No. 47] incrusts the charcoal with oxides of lead and zinc, the presence of the first of which is indicated by the colour of the incrustation, and by the pale-blue colour imparted to the reducing flame (see par. 27). Zinc is best detected by moistening the charcoal near to the assay with cobalt solution and

re-heating, when the green colour due to zinc is easily distinguished from the lead incrustation.

An alloy of *lead* and *bismuth* [No. 46] gives a somewhat darker incrustation than does pure lead. Bismuth is detected according to par. 122; lead is recognized by the pale-blue colour imparted to the reducing flame.

154. To detect lead in *sulphides*, the assay is heated on charcoal in the reducing flame, whereby the incrustation due to lead is produced. An admixture of antimony cannot here be detected, since the film of lead sulphate which surrounds the oxide incrustation may easily be mistaken for the antimony oxide incrustation.

In order to detect antimony at the same time in such a case, it is sufficient to powder the assay [No. 81], mix with sodium carbonate, and heat for a short time only in the reducing flame. In absence of antimony, the incrustation is a pure yellow with a bluish-white border; in presence of antimony, the incrustation is surrounded by a white film of antimony oxide, and the incrustation has a dark, orange-yellow colour from the formation of lead antimonate. If the mixture be heated too long, sodium sulphide will volatilize, and an incrustation of sodium sulphate will be deposited.

155. If lead sulphate occurs with a large amount of copper sulphate [No. 24], the metallic bead obtained by reduction does not show the presence of lead, but a strong oxidizing flame will volatilize the lead and produce an incrustation.

Lead chloride fuses before the blowpipe flame, and yields two incrustations: a white volatile one of chloride, and a less volatile one of oxide. In addition, the reducing flame is coloured pale-blue.

Lead phosphate fuses alone to a bead on charcoal with the formation of very little or no incrustation. On cooling, the bead crystallizes with large white facets of a pearly lustre.

Lithium. The reactions of lithium and its compounds are given in par. 52 and No. 3 of the table at the end of the book.

156. *Silicates* which contain only small quantities of lithium are made into a paste with one part of fluorspar, one and a half parts of hydrogen potassium sulphate, and a drop or two of water, and then heated for flame-coloration on a platinum loop [No. 63]. If the silicate also contains boric acid, as in tourmaline, a green flame is first obtained, and then a red one.

The presence of phosphoric acid, as in the case of triphylite for example, causes a green flame, perceptible along with the red one, especially after moistening with sulphuric acid.

Lithium, in presence of sodium, can also be detected by plunging the assay, moistened with hydrochloric acid, into molten wax or tallow, and then holding in the non-luminous flame; a carmine flame is then momentarily produced,

Manganese. For the reactions of manganese and its compounds, see pars. 41, 60, 62, 104 and No. 32 of the table at the end of the book.

157. If a bead containing manganese, just removed from the oxidizing flame, be brought into contact with a crystal of potassium nitrate or chlorate, or be thrown into a porcelain capsule containing the powdered reagent, a violet frothlike mass of potassium permanganate is produced.

158. To detect the smallest quantity of manganese in any compound, the assay [No. 62 or 80] is fused with two parts of sodium carbonate and one part of potassium nitrate, on platinum wire or foil, in the oxidizing flame. Potassium manganate is thus formed, which is green and clear whilst hot, and becomes bluish-green and opaque on cooling. With water, a green solution is obtained, which becomes red on the addition of acetic acid, and afterwards colourless, frequently with the separation of brown flakes.

The simultaneous presence of silica and cobalt hinders the reaction, a blue mass being formed which obscures the green colour. In this extremely rare case the silica must first be separated in the wet way. Should chromium be present, the colour of the product is yellowish-green.

159. To detect manganese in metallic compounds, or in metallurgical products, the substance is dissolved in nitric acid, the solution is evaporated to dryness, and the ignited residue is tested with sodium carbonate and potassium nitrate as above.

Mercury. For the reactions of mercury and its compounds, see pars. 11, 17, 62, 81, and No. 33 of the table at the end of the book.

160. *Amalgams*, when heated in a tube close at one end, give a sublimate of metallic mercury in the form of minute globules which are best seen under a lens [No. 44].

In combination with *sulphur* [No. 77], *chlorine* [No. 42], *iodine* or *oxyacids*, the assay is heated with dry sodium carbonate. The acid or halogen remains combined with the soda, whilst the mercury sublimes.

If the quantity of mercury is so small that the sublimate cannot be clearly seen, the experiment is repeated, and a bit of gold leaf wrapped around an iron wire is passed down the tube near to the assay. The smallest quantity of mercury suffices to turn the gold white.

Molybdenum. For the reactions of molybdenum and its compounds, see pars. 39, 41, 48, 62, 63, 67, 99, and No. 34 of the table at the end of the book.

161. Small quantities of molybdic acid may be readily detected as follows: A little of the powdered substance is added to some concentrated sulphuric acid on a tray-shaped piece of platinum foil; after heating until brisk evaporation sets in, and then cooling, the foil is repeatedly breathed upon. Where only blue spots appear on cooling an intense blue colour is produced by breathing. The reaction succeeds still better if, instead of breathing upon the foil, a little alcohol be added; the characteristic blue colour then appears either at once or immediately after burning off the alcohol (Von Kobell). This blue oxide is also produced by the iodine sulphide reaction (par. 63).

Nickel. For the reactions of nickel and its compounds, see pars. 41, 62, 88 and No. 35 of the table at the end of the book.

162. *Fusible metallic compounds* of nickel are treated on charcoal with borax in the reducing flame, by which means iron, cobalt, &c., are taken up by the glass (for examination see par. 132), whilst the metals whose oxides are easily reduced remain behind. This operation is repeated until the glass remains colourless. The residual metallic bead is then treated with microcosmic salt in the oxidizing flame, when a pure yellow colour due to nickel, or a yellowish-green colour due to nickel and copper,

is produced. In the latter case the glass is reduced on charcoal with tin to confirm the presence of copper. Antimony and bismuth, whose presence obscures this reaction by blackening the bead, must be expelled by roasting previous to the addition of the flux [No. 78].

In *arsenic* and *sulphur* compounds, the search for nickel is conducted as in the case of cobalt (see par. 133).

163. To detect small quantities of nickel in presence of *cobalt* the following method may be adopted: A not too small quantity of the assay is dissolved in borax on platinum wire, and the dark-coloured bead is thrown off and treated with a small gold bead on charcoal in the reducing flame. When cold, the gold bead is separated from the slag by a tap from a hammer, and is fused with microcosmic salt in the oxidizing flame. The glass takes up the easily soluble cobalt oxide, becoming blue; and fresh quantities must be added until the colour changes to green, and finally becomes yellow. The gold is afterwards refined by cupelling with lead on bone-ash.

164. **Nitric Acid.** On heating the perfectly dry substance [No. 36] in a small matrass with hydrogen potassium sulphate, reddish-brown nitrous fumes are evolved. If a slip of paper moistened with ferrous sulphate solution be placed in the neck of the matrass, which should be rather long for this purpose, the paper in presence of nitric acid becomes yellow or brown.

Since chlorine affords a similar reaction, it is necessary, when chlorine compounds are present, to use litharge free from lead peroxide instead of the hydrogen potassium sulphate. This oxide at first absorbs the nitric acid, but gives it off again at a higher temperature.

Phosphoric Acid. For the reactions of phosphoric acid, see pars. 46 and 107.

165. The powdered substance is placed in a drawn-out glass tube closed at the bottom, and a piece of magnesium wire about 5 mm. long, or a bit of sodium, is added, and surrounded entirely by the assay. On heating, the mass becomes incandescent, and phosphide of magnesium or sodium is formed. On crushing the tube and moistening its contents with water, the characteristic odour of hydrogen phosphide is perceived [No. 64].

166. Potassium. Flame coloration best serves to detect potassium (see pars. 50 and 58). Another less useful reaction is obtained by charging a borax bead with nickel oxide in the oxidizing flame; the brown bead thus produced is coloured violet on the addition of a potassium salt. Sodium and lithium do not interfere, but a minute amount of cobalt present, either in the nickel oxide or in the potassium compound, prevents the reaction.

167. Selenium. The reactions of selenium (pars. 11, 19, 37, 60, 63, and 77) are very characteristic. In non-volatile compounds, which do not yield the red sublimate mentioned in par. 11, this element is easily detected by the odour of rotten horse-radish which the substance [No. 83] evolves when heated on charcoal in the oxidizing flame; when much selenium is present, an incrustation is also produced in this case (see par. 37). Selenates and selenites are reduced with sodium carbonate on charcoal, whereupon the peculiar odour is perceived.

Silicon. The reactions of silicic acid are given in par. 106 and No. 15 of the table at the end of the book.

168. When a silicate in the form of a splinter (not in powder) is heated in a microcosmic bead, it is generally so decomposed that the bases combine with the free phosphoric acid to a transparent glass, in which the separated silica floats about in a form similar to that of the original splinter [No. 57]. Some silicates, however, dissolve completely, but the silica in such can usually be detected if the bead is observed before the splinter has completely disappeared, more especially after the repeated addition of fresh portions in the form of small splinters. In all cases the appearance of the bead whilst still hot is noted, as many silicates afford glasses which become turbid on cooling. On testing various silicates by this method, differences will be observed, due to the greater or less facility with which they are decomposed. An easily decomposable splinter, when a certain temperature is reached, will be seen to swell up and decompose; the remainder then collects together again to form a delicate transparent flake of silica; this is frequently accompanied by a brisk evolution of gas. Other silicates are not so readily attacked; the splinter requires heating in the bead for a considerable time, during which it gradually becomes a transparent mass of silica, smaller perhaps than the original splinter, but of the same form. There is thus formed a silica *skeleton*. Here also gas is frequently evolved, especially at the beginning of the reaction (serpentine, steatite). Lastly, there are silicates which in the form of splinters do not appear to be attacked in the microcosmic bead, and the distinction between these refractory silicates and those which afford a skeleton is less marked than is the distinction between skeleton-forming and flake-forming silicates. These distinctions are of importance in mineralogy, as it is thus possible, for example, to distinguish in a very simple manner between small splinters of vesuvianite and garnet, of epidote and augite, of tourmaline and beryl, of scapolite and felspar, &c. (Haushofer).

Silver. For the reactions of silver and its compounds, see pars. 29, 62, 63, 96, and No. 42 of the table at the end of the book.

169. Silver in combination with *volatile metals* (bismuth, lead, zinc, antimony) is ignited strongly on charcoal, when after volatilization of these metals, a bead of silver surrounded by a reddish incrustation remains. A large amount of lead or bismuth is best removed by cupellation. This operation is conducted as follows : Finely powdered bone-ash together with a little sodium carbonate is mixed with water to a stiff paste, and this is placed in a hole bored in the charcoal. The surface of the paste is hollowed out a little and smoothed by means of an agate pestle, and the mass is dried by warming gently. On this small cupel the substance is heated until all the bismuth and lead is oxidized and more or less completely absorbed by the bone-ash. The silver, or the alloy if gold be also present, remains behind as a brilliant metallic bead [No. 48].

170. Alloyed with *copper nickel*, and other oxidizable, non-volatile metals, silver is detected by treatment with borax or microcosmic salt in the oxidizing flame. The silver remains behind, whilst the other metals are oxidized and absorbed by the flux. If the amount of silver be small in comparison with that of the other metals, the following method for the detection of this along with any gold that may be present, is recommended.

171. The substance [No. 82] is powdered and placed with fused and powdered borax and assay-lead in a cylindrical hole in charcoal. To one part of the assay are added one part borax-glass, and from 5 to 10 parts assay-lead, according to the smaller or greater amount of non-volatile metals present. A powerful reducing flame is applied until the metal unites to a bead and the slag is freed from small metallic globules. An oxidizing flame is next applied, and is mainly directed on to the metallic bead. Sulphur, arsenic, antimony, and other volatile constituents are removed, whilst iron, tin, and cobalt, as well as some copper and nickel, are oxidized and taken up by the flux. Silver, gold, and the greater part of the copper and nickel remain with the lead and with any bismuth that may be present. As soon as the volatile constituents are all removed, the lead itself begins to oxidize, the bead acquiring a rotatory movement. At this point the mass is allowed to cool, and the lead bead is separated from the glass by tapping with a hammer. The bead is laid on a cupel and again heated until rotation re-commences. When copper and nickel are present in large quantities, the bead becomes covered with a thick infusible crust of oxide, which prevents the desired oxidation, and in this case the addition of a little more assay-lead is requisite. The heating is now continued until all the lead, copper, nickel, &c., is oxidized. When the silver is small in amount, this point is recognized by the cessation of the rotatory motion; with a larger amount of silver, thin films having all the colours of the rainbow coat the bead just before the end of the process, and after a few seconds, the bead assumes the lustrous appearance of pure silver. The oxides of lead,

copper, &c., are absorbed by the bone-ash and pure silver, or an alloy of silver with other noble metals, remains behind. Gold is sought for according to par. 142.

Silver chloride, when treated on charcoal with sodium carbonate, is reduced to metal.

Sulphur. For the reaction of sulphur in sulphides, see pars. 11, 14, and 21, section 5. In examination for sulphur, a coal-gas flame should never be employed on account of the large amount of sulphur compounds contained in the gas.

172. A sensitive as well as readily applicable method for the detection of sulphur in any of its compounds consists in heating the powdered substance with pure sodium carbonate, or preferably (to prevent absorption by the charcoal), with sodium carbonate to which half its weight of borax has been added. The mixture is heated to fusion on charcoal in the reducing flame. The fused mass is separated from the charcoal, brought on to a piece of silver foil or coin, and moistened with water. If sulphur be present, a black stain of silver sulphide is produced on the metal. Since selenium and tellurium afford the same reaction, their absence must be assured.

If a substance containing sulphur is heated with sodium carbonate in the reducing flame, the mass next moistened on a watch-glass with water, and then a little sodium nitroferricyanide added, a magnificent purple-red colour is produced.

A dilute solution of ammonium molybdate to which excess of hydrochloric acid has been added, assumes a beautiful blue colour on the addition of hydrogen sulphide, or a soluble sulphide.

From sulphides, hydrochloric or sulphuric acid liberates hydrogen sulphide, which is easily detected by its odour and by its blackening a slip of paper which has been dipped in lead acetate solution.

173. To distinguish between sulphides and sulphates, the substance under examination is heated in the oxidizing flame, when only sulphides yield the odour of sulphur dioxide. Another method is as follows: The finely powdered substance [No. 75] is fused with caustic potash in a platinum spoon, and the spoon with its contents is thrown into water containing a strip of silver. If the silver remains quite white, the sulphur is present as sulphate; if the silver becomes black, sulphur is present as sulphide. Substances exercising a reducing action must of course not be present.

Tellurium. For the reactions of tellurium and its compounds, see pars. 11, 18, 38, 63, 76, and No. 44 of the table at the end of the book.

174. *Lead* and *bismuth*, which render the detection of tellurium difficult on charcoal, may be taken up by fused boric acid in the reducing flame, when the formation of a tellurium incrustation will not be prevented.

If the incrustation disappears under the reducing flame, not with a green, but with a bluish-green flame-coloration, selenium is also present, which is easily recognized by its odour.

A powdered tellurium compound heated with sodium carbonate and charcoal powder in a matrass, and treated when cold with hot water, yields a purple-red solution of sodium telluride.

When tellurides are gently warmed with sulphuric acid, the tellurium is dissolved without oxidation, and the solution possesses an intense carmine-red colour.

Water reprecipitates the tellurium as a blackish-grey powder.

Tin. For the reactions of tin and its compounds, see pars. 12, 28, 61, 62, 63, 98, and No. 46 of the table at the end of the book. If a small quantity of a tin compound be added to a borax bead coloured blue by copper oxide, and the reducing flame be applied, the bead becomes brown.

175. Substances containing tin in an oxidized state are heated on charcoal with sodium carbonate and borax in the reducing flame. Malleable and easily fusible beads of metallic tin are thus obtained. If these be separated from the slag, and heated in the oxidizing flame, they are converted into white oxide, which is deposited on the charcoal in the immediate neighbourhood of the assay. By treatment with cobalt solution the incrustation becomes bluish-green. When occurring together with zinc, with which its reactions are very similar, tin can be detected by the iodide film (see par. 63). Sulphides are roasted, and then examined as above.

176. In metallic alloys tin is easily detected, since the bead cannot be kept bright and free from oxide even in the strongest reducing flame.

Alloys of copper and tin (gun-metal, bell-metal, and bronze) are examined as follows: The substance is fused with a flux consisting of one part of sodium carbonate, half a part of borax, and one-third part of silica in the reducing flame, until the metallic bead takes up a rotatory motion. The oxidizing flame is then applied mainly to the glass, and so that the bead may be in contact on one side with the glass, and on the other with the charcoal. The tin becomes oxidized and is absorbed by the glass, whilst the copper remains behind. The latter is separated from the glass, and further treated with microcosmic salt, whilst the slag is pulverized and reduced on charcoal with carbonate of soda or of potash [No. 49].

Titanium. The reactions of titanium are given in pars. 41, 59, 61, 67, 101, and No. 47 of the table at the end of the book.

177. If titanic acid forms the main constituent of a mineral, it can easily be detected by its reactions with fluxes. When iron is present at the same time, microcosmic salt in the oxidizing flame gives the iron colour, and in the reducing flame a blood-red bead, which on charcoal with tin becomes violet.

Compounds which give indefinite results with fluxes are treated as follows: The substance is fused with six to eight times its weight of hydrogen potassium sulphate in a platinum spoon, dissolved in cold water, filtered, and, after addition of a drop or two of nitric acid, is heated to boiling. A white precipitate of metatitanic hydrate is formed, and this can be further examined with microcosmic salt [No. 61].

If titanic oxide be fused with caustic potash, dissolved in water, and the solution evaporated after addition of an excess of hydrochloric acid and a piece of tin foil, the liquid becomes violet coloured, and, on dilution with water, rose-red.

Very characteristic of titanium are the crystals produced by titanic oxide in fluxes. According to G. Rose, a transparent microcosmic bead, coloured violet in the reducing flame from the presence of titanium, becomes quite clear, if not oversaturated, when held in the outer flame near to the blue point; whilst at the point of the non-luminous flame it becomes opalescent, and when more strongly saturated, it becomes snow-white and opaque. On bringing the bead to the point of the blue flame, it becomes clear again, and in the inner flame it again acquires a violet colour. The hot opalescent bead, if flattened and examined under a magnifying power of 140 diameters, shows well-formed, lustrous, transparent, quadratic tables, partly collected in groups, which are seen to exhibit double refraction under polarized light, and may be considered to be anatase. According to Knop, however, the crystals belong to the rhombic system, and consist of titanium phosphate.

Titanic oxide gives with borax on charcoal in the reducing flame a yellowish-brown bead, or if strongly saturated, a light- to dark-blue bead. From this dark-blue glass crystals of rutile separate out, without destroying the transparency of the bead. The crystals occur as long quadratic prisms, variously terminated, and having their lateral edges replaced by planes. With a mixture of borax and microcosmic salt, the crystals occur in very regular forms.

Tungsten. The reactions of tungsten and its compounds are given in pars. 41, 59, 63, 67, 100, and No. 48 of the table at the end of the book.

178. Tungsten, when present in small quantity, is detected as follows: The assay is fused with five times its weight of sodium carbonate, the mass extracted with water, and the tungstic acid precipitated by hydrochloric acid in the form of a white powder. The precipitate becomes yellow on boiling, and is insoluble in excess of the acid (distinction from molybdic acid), but dissolves in ammonia. The solution, after acidification, gives a

deep brown coloration with potassium ferrocyanide, and after some time a precipitate of the same colour separates; with silver nitrate a white, and with stannous chloride, a yellow precipitate is produced. On acidifying with hydrochloric acid and warming, the precipitate becomes a beautiful blue colour which is very characteristic.

Uranium. For the reactions of uranium and its compounds, see pars. 41, 62, 105, and No. 49 of the table at the end of the book.

179. In compounds containing no other colour-producing constituent, the metal can be detected by its reaction with microcosmic salt as well as by the reactions referred to above. Since *iron* and uranium behave similarly towards fluxes, the method given in par. 151 must be applied to distinguish between the two.

Along with *copper* oxide, uranium (like iron, and in similar quantity) produces a green bead in the oxidizing flame. To detect the uranium in such a case, the substance is treated with sodium carbonate, borax and a silver bead on charcoal in the reducing flame, until all the copper is reduced and taken up by the silver. The slag is dissolved in nitric acid, the solution treated with ammonium carbonate, and examined further according to par. 151.

Vanadium. For the reactions of vanadium and its compounds, see pars. 41, 59, 67, 103, and No. 50 of the table at the end of the book.

180. On fusing vanadium compounds with sodium carbonate and potassium nitrate on a platinum spiral, extracting with water, acidifying with acetic acid, and adding silver nitrate, a yellow precipitate is obtained.

By evaporating the fused mass with aqua-regia, a yellow or yellowish-brown solution results, which becomes blue on the addition of stannous chloride.

If the solution obtained by extracting the fused mass be acidified and well shaken with hydrogen peroxide, it becomes red, and retains this colour on the addition of ether, the latter remaining uncoloured.

Zinc. The reactions of zinc in its compounds are given in pars. 12, 35, 61, 62, 63, 85, and No. 51 of the table at the end of the book.

181. Substances containing zinc in an oxidized or sulphurized condition are heated alone on charcoal in the reducing flame; such as contain other metallic oxides are heated with a mixture of two parts of sodium carbonate and one and a half parts of borax. The incrustation which forms is very characteristic, since it becomes luminous when strongly heated, is yellow when hot, and white on cooling, is non-volatile, and acquires a green colour when moistened with cobalt solution and re-heated. It is advisable to previously moisten with the solution the charcoal about where the incrustation will be deposited.

182. Whilst the reaction with cobalt solution is unprejudiced by the presence of lead and bismuth, it is inapplicable in the presence of tin and antimony, since they give similar reactions. Sometimes it is possible to expel antimony with the oxidizing flame; in most cases, however, zinc cannot be detected before the blowpipe in the presence of the two last-named metals.

CHAPTER IV.

SYSTEMATIC EXAMINATION OF COMPOUND INORGANIC SUBSTANCES.

183. Although it is not difficult to detect the constituents of a substance, after a little practice with the blowpipe, by aid of the reactions described in the two last chapters, still it is advisable in many cases to follow a systematic course of investigation. Time is thus often economized, and more definite and satisfactory results are obtained.

It is not to be expected that the several constituents of a substance can be detected by successive decompositions, as is the case in the wet method of analysis. Except in the parting of volatile and non-volatile substances, separations cannot easily be effected in the dry way. A blowpipe course is consequently little more than a methodical series of single tests. Since fresh portions of the original substance are being frequently taken, only small quantities should be used at the commencement.

In the following pages two different methods are given, either of which can be followed, according to the skill of the operator, or the nature of the object under examination.

The first method supplements the courses already given in this work, and presupposes a moderate amount of experience. It is applicable to all kinds of substances, and leads at the same time to the essential confirmatory tests.

Egleston's method is somewhat shorter in the case of metallic compounds; but to obtain satisfactory results with it greater experience is required.

I. SYSTEMATIC EXAMINATION OF COMPOUND SUBSTANCES.*

PRELIMINARY EXAMINATION.

A. THE SUBSTANCE IS HEATED IN A TUBE CLOSED AT ONE END.

a. *Gaseous substances evolved:*

Colourless and Odourless.	*Colourless, with Odour.*	*With Colour and Odour.*
Water; Water of crystallization; water of hydration. **Oxygen**; Peroxides, nitrates, chlorates, bromates, and iodates. **Carbon dioxide**; Many carbonates and oxalates. **Carbon monoxide**; Oxalates and formates (the latter blacken).	**Sulphur dioxide**; Sulphites and some sulphates. **Hydrogen sulphide**; Hyposulphites and sulphides containing water. **Ammonia**; Some ammonium salts.	**Nitrous fumes**; Most nitrates and nitrites. **Iodine** (violet); Some iodides and iodates. **Bromine** (brown); Some bromides. **Chlorine** (greenish-yellow); Some chlorides.

b. *Sublimate formed:*

White Sublimate.	*Black or Grey Sublimate.*	*Coloured Sublimate.*
Ammonium salts. **Mercurous chloride**; Sublimes without previous fusion.	**Arsenic**; Metallic arsenic and many arsenic compounds (metallic mirror).	**Sulphur**; Hot, yellowish-brown; cold, yellow.

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* Landauer, *Zeitschrift für analytische Chemie*, XVI. 385.

b. *Sublimate formed.*—Continued :

White Sublimate.	*Black or Grey Sublimate.*	*Coloured Sublimate.*
Mercuric chloride ; Fuses previously. **Antimony oxide** ; Fuses and sublimes to lustrous needles. **Tellurium dioxide** ; Fuses and sublimes to an amorphous mass. **Arsenic trioxide** ; Sublimes without fusion to octohedral crystals.	**Mercury amalgams**, and some mercury compounds (metallic beads).	**Antimony sulphide** ; Hot, black ; cold, reddish-yellow. **Arsenic sulphide** ; Hot, brown-red ; cold, reddish-yellow. **Mercuric iodide** ; Yellow, becoming red on rubbing. **Mercuric sulphide** ; Black, becoming red on rubbing. **Selenium** ; Reddish to black ; powder, dark red.

c. *Change of colour* :

Zinc oxide ; from white to yellow ; cold, white.
Tin oxide ; from white to yellowish-brown ; cold, light yellow.
Lead oxide ; from white to brownish-red ; cold, yellow.
Bismuth oxide ; from white to orange-yellow ; cold, lemon-yellow.
Mercuric oxide ; from red to black ; cold, red (volatile).
Ferric oxide ; from red to black ; cold, red (non-volatile).
Mercuric iodide ; from red to yellow ; cold, red.
Hydrated salts of cobalt, nickel, iron, and copper.

d. *Fusion* : Salts of the alkalis.

e. *Carbonization* : Organic substances.

f. *Phosphorescence* : Alkaline earths, earths, zinc oxide, tin oxide.

g. *Decrepitation* : Alkaline chlorides, galena, and many minerals.

B. THE SUBSTANCE IS HEATED IN AN OPEN TUBE.

(Reactions given under *A* are not repeated.)

a. *Gaseous substances evolved:*

Sulphur dioxide; of characteristic odour: Sulphur and sulphides.

Selenium dioxide; smelling of rotten horse-radish: Selenium and selenides.

b. *Sublimate formed:*

Arsenic trioxide; white, very volatile sublimate deposited at some distance from the assay: Arsenic and arsenides.

Antimony oxide; white fumes: sublimate partly volatile: Antimony and its compounds.

Tellurium dioxide; white fumes; sublimate fusible to colourless drops: Tellurium and tellurides.

Lead sulphate;
Bismuth sulphate; White, found chiefly beneath the assay: Sulphur compounds of lead and bismuth respectively.

C. THE SUBSTANCE IS HEATED ON CHARCOAL.

a. *As regards Fusibility:*

Fusible.	*Infusible.*
Salts of the alkalis and of some of the alkaline earths.	Salts of the earths and of the alkaline earths, silica.
Antimony, lead, cadmium, tellurium, bismuth, zinc, tin (all easily fusible).	Iron, cobalt, nickel, manganese, molybdenum, tungsten, platinum, palladium, iridium, rhodium, and osmium.
Copper, gold, silver (difficultly fusible).	

b. *Detonation:*

Nitrates, chlorates, iodates, and bromates.

c. *Intumescence:*

Substances yielding water, borates and alum.

Flame-coloration, *Reduction*, and *Formation of incrustations* are described subsequently.

COMPLETE EXAMINATION.

EXAMINATION FOR BASES.

I. The substance is treated with sodium carbonate on charcoal in the reducing flame (with metals and alloys the carbonate is omitted).

If any of the following group reactions appear alone, the course may be shortened, as follows:

a. The substance gives an incrustation. Begin section I., No. 1.

b. The substance gives a metallic bead without incrustation. Begin section I., No. 10.

c. The substance leaves a grey or black residue. Begin section II., No. 13.

d. The substance colours the flame, especially after moistening with HCl. Begin section IV., No. 32.

e. The substance gives a white luminous residue. Begin section V., No. 43.

f. The substance volatilizes completely. Begin section VI., No. 52.

1. *Incrustation, white,* and very volatile, disappearing with light blue flame, and odour of garlic. **Arsenic.**

1*a. Confirmation.* On heating with potassium cyanide and sodium carbonate in matrass, an arsenic mirror is formed.

2. *Incrustation, reddish-brown,* with coloured tarnish having resemblance to the eyes of a peacock feather, disappearing without flame-coloration in O. or R. Fl. **Cadmium.**

2*a. Confirmation.* The incrustation scraped off and heated with sodium hyposulphite in a tube closed at one end becomes hot cinnabar red, cold yellow. See also 3*a*.

3. *Incrustation*, hot, *yellow*, cold, *white*, luminous, and is non-volatile under the flame. **Zinc.**

3*a*. *Confirmation.* The incrustation heated with cobalt nitrate solution becomes green. When Cd and Zn occur together, the Cd incrustation appears first, and afterwards that of the Zn.

4. *Incrustation*, *steel-grey*, disappearing in the R. Fl. with blue coloration and odour of rotten horse-radish. **Selenium.**

4*a*. *Confirmation.* See 5*a*.

5. *Incrustation*, *white*, with dark yellow to red border, disappearing in the R. Fl. with green coloration. **Tellurium.**

5*a*. *Confirmation.* If Se and Te occur together, a white incrustation is produced which colours the R. Fl. bluish-green, and gives off an odour of rotten horse-radish. To distinguish these, a metallic film is produced, and this is moistened with concentrated H_2SO_4, and *gently* warmed. Te dissolves immediately with a carmine-red colour, whilst the dirty-green colour of Se appears after heating more strongly.

6. *Incrustation*, *bluish-white*, and volatile, disappearing under O. Fl. and R. Fl., in the latter case with green coloration. *Bead*, white, brittle and oxidizable. **Antimony.**

6*a*. *Confirmation.* The incrustation scraped off and treated with HCl and Zn on platinum foil covers the latter with an adherent black film of antimony.

7. *Incrustation*, hot, *orange*, cold, *lemon-yellow*, disappearing under O. or R. Fl. without flame-coloration. *Bead*, reddish-white, brittle and oxidizable. **Bismuth.**

7*a*. *Confirmation.* On charcoal, with potassium iodide and sulphur, or with iodine sulphide, in the O. Fl. gives a beautiful red incrustation of bismuth iodide.

8. *Incrustation*, hot, *lemon-yellow*, cold, *sulphur-yellow*, disappearing in O. and R. Fl. colouring the latter a beautiful blue. *Bead*, grey, malleable and oxidizable. **Lead.**

8*a*. *Confirmation.* Treat the substance with HNO_3, evaporate off excess of acid, add a little H_2SO_4, and evaporate until white acid vapours appear. A white powder remains, insoluble in dilute H_2SO_4.

9. *Incrustation*, hot, *yellowish*, cold, *white*, small in quan-

tity deposited close to the assay and non-volatile. *Bead*, white, malleable and very oxidizable. **Tin.**

9*a*. *Confirmation*. Dissolve in HCl, and precipitate Sn, as a grey, spongy mass, from the acid solution by means of metallic Zn. The separated Sn does not adhere to Pt (distinction from Sb). A crystal of sodium hyposulphite thrown into the solution (containing HCl and Zn) produces a precipitate of brown SnS.

10. *Bead*, *white*, malleable and very brilliant. In strong O. Fl. a reddish-brown incrustation is formed, which becomes carmine-red in presence of Pb and Sb. **Silver.**

10*a*. *Confirmation*. When dissolved in HNO_3, and HCl added, a white curdy precipitate of AgCl is obtained.

11. *Bead*, *yellow*, very brilliant, malleable and non-oxidizable. **Gold.**

11*a*. *Confirmation*. Dissolve in aqua-regia, and obtain a precipitate of purple of Cassius with $SnCl_2$.

12. *Red metal*, ductile and oxidizable. **Copper.**

12*a*. *Confirmation*. See Nos. 13 and 39.

REMARKS.

The following metals are obtained in the form of grey, infusible powder: iron, nickel, and cobalt, which are magnetic, and molybdenum, tungsten, and the metals of the platinum group; the platinum metals cannot be clearly individualized by blowpipe reactions, but the remainder of the above-named metals give characteristic reactions with borax (Section II).

Chromium compounds yield a yellow, and manganese compounds a green mass with sodium carbonate. These are detected in Section II.

Some chlorides, iodides, bromides, and sulphides yield white, not very characteristic incrustations, without giving a metallic bead; these incrustations should not be confounded with those given above. The substances which yield these incrustations are otherwise detected in due course.

Evolution of hydrogen sulphide, recognized by its odour, indicates a sulphate or sulphide.

II. The assay (residue) is dissolved in borax on platinum wire.

a. A coloured bead is produced in O. or R. Fl. No. 13.
b. Bead is not coloured. Section IV., No. 32.

The colour of the bead is :

	In the Oxidizing Flame.		*In the Reducing Flame.*		
	Hot.	Cold.	Hot.	Cold.	
13	Green.	Bluish-green.	Colourless.	Brown.	**Copper.**
14	Blue.	Blue.	Blue.	Blue.	**Cobalt.**
15	Violet to black.	Reddish-violet.	Colourless.	Colourless to rose-coloured.	**Manganese.**
16	Violet.	Reddish-brown.	Yellowish-grey.	Yellowish-grey.	**Nickel.**
17	Red, in small quantity yellow.	Colourless.	Green.	Bottle-green.	**Iron.**

13*a*. *Confirmation.* The microcosmic bead becomes red when reduced with Sn ; if it becomes black the substance is roasted on charcoal, and Sb and Bi are removed with boric acid (O. Fl.).

14*a*. *Confirmation.* The metal reduced on charcoal, and taken up on paper, gives a red solution with HNO_3; on adding HCl and drying, a green stain results, which disappears on moistening with H_2O.

15*a*. *Confirmation.* On fusing with Na_2CO_3 and KNO_3 on platinum, a green mass results.

16*a*. *Confirmation.* The metal reduced on charcoal, taken up on paper, and moistened with HNO_3, gives a green solution, which produces an apple-green stain with Na_2CO_3.

17*a*. *Confirmation.* The metal reduced on charcoal, taken up on paper, and moistened with HNO_3 and HCl, gives a yellow stain on drying, which becomes blue on adding potassium ferrocyanide.

II. The assay—*Continued.*

	In the Oxidizing Flame.		*In the Reducing Flame.*		
	Hot.	Cold.	Hot.	Cold.	
18	Red, in small quantity yellow.	Colourless.	Green.	Bottle-green.	**Uranium.**
19	Do.	Do., strongly satd. opaline.	Brown.	Brown (turbid).	**Molybdenum.**
20	Do.	Grass-green.	Green.	Emerald-green.	**Chromium.**
21	Do.	Colourless, strongly satd. yellow.	Colourless.	Colourless.	**Cerium.**
22	Do.	Greenish-yellow.	Brownish.	Emerald-green.	**Vanadium.**
23	Do.	Colourless, strongly sat. enam. white.	Yellow.	Yellowish-brown.	**Tungsten.**
24	Do.	Colourless.	Yellow to brown.	Yellow to brown, by flaming blue.	**Titanium.**

18*a*. *Confirmation.* The microcosmic bead in the O. Fl., *hot*, yellow, *cold*, yellowish-green ; R. Fl., *hot*, dirty-green, *cold*, beautiful green (distinction from iron). Insoluble uranium compounds are fused with $HKSO_4$ on a platinum spiral, the fused mass is ground up with Na_2CO_3, and, after moistening, is taken up on paper. After acidifying with acetic acid, potassium ferrocyanide gives a brown stain.

19*a*. *Confirmation.* On digesting with H_2SO_4 in a platinum spoon, and then adding alcohol or breathing upon it, the MoO_3 colours the acid deep blue. The blue iodide film is also characteristic.

20*a*. *Confirmation.* A yellow mass is obtained on fusing with Na_2CO_3 and KNO_3 on platinum foil.

21*a*. *Confirmation.* Cannot be detected with absolute certainty by the blowpipe.

22*a*. *Confirmation.* After fusion with Na_2CO_3 and KNO_3, extraction with H_2O, and acidification with acetic acid, a yellow precipitate is produced by $AgNO_3$.

23*a*. *Confirmation.* The microcosmic bead is in the O. Fl., *hot* and *cold*, colourless ; R. Fl., *hot*, dirty-green, and *cold*, blue ; after the addition of Fe blood-red. See No. 27.

24*a*. *Confirmation.* The microcosmic bead is in the O. Fl., *hot* and *cold*, colourless ; R. Fl., *hot*, yellow, *cold*, violet ; after the addition of Fe blood-red. See No. 30.

25. The bead shows double reactions from the presence of several colouring oxides, *e.g.*

In Oxidizing Flame.		*In Reducing Flame.*		
Hot.	Cold.	Hot.	Cold.	
Violet to blood-red.	Brownish-violet.	Yellow.	Bottle-green.	Mn and Fe.
Plum-colour.	Plum-colour.	Bluish-green.	Blue.	Mn, Fe, and Co.
Green.	Grey-blue.	Bluish-green.	Green.	Mn, Fe, Co, Ni.
Yellowish-green.	Green.	Greenish-blue.	Blue.	Fe, Co, little Ni.
Violet-brown.	Brown.	Blue.	Blue.	Co and much Ni.
Green.	Light green, blue, or yellow, according to saturation.			Fe and Co. Fe and Cu. Fe and Ni.

25*a*. *Special examination.* Several borax beads are saturated with the substance, and tossed off the wire; they are then reduced on charcoal with the addition of a little lead. After a short time the glass is separated from the metallic bead, and these separately examined:

A. Fragments of the *glass* are dissolved in borax on Pt wire:

α. The bead is blue. **Co.**

β. The bead is *hot*, green, *cold*, blue (O. Fl.). **Fe** and **Co.**

γ. The bead is *hot*, violet to blood-red, *cold*, brownish-violet (O. Fl.): *hot*, yellow, *cold*, bottle-green (R. Fl.): on charcoal with Sn reduced to vitriol-green. By incomplete oxidation the bead is, *hot*, yellow, *cold*, colourless. **Mn** and **Fe.**

δ. The bead is, *hot* and *cold*, plum-coloured (O. Fl.); *hot*, bluish-green, and *cold*, blue (R. Fl.). **Mn, Fe,** and **Co.**

B. The *lead bead* is treated with boric acid on charcoal (O. Fl.) to remove the lead, and the residue is dissolved in microcosmic salt :

α. The bead is *cold*, blue (O. Fl.) ; reduced with Sn on charcoal, red. **Cu.**

β. The bead is, *cold*, yellow (O. Fl.). **Ni.**

γ. The bead is, *cold*, green (O. Fl.). **Cu** and **Ni.**

III. **The substance is fused with hydrogen potassium sulphate, and a strip of zinc is placed in the solution after acidification with HCl.** (To be omitted if W, V, Ti, and Nb are not to be sought for.)

The solution becomes coloured as follows :

26. Blue, then green, and finally dark-brown. **Molybdic acid.**

26*a*. *Confirmation*. Already found by No. 19.

27. Blue, then copper-red. **Tungstic acid.**

27*a*. *Confirmation*. See No. 23.

28. Blue, then green, and lastly violet. **Vanadic acid.**

28*a*. *Confirmation*. See No. 22.

29. Green. **Chromic acid.**

29*a*. *Confirmation*. Already found by No. 20.

30. Violet. **Titanic acid.**

30*a*. *Confirmation*. See No. 24.

31. Blue ; strongly acid solution, brown. **Niobic acid.**

IV. The substance is brought into the non-luminous flame on platinum wire, or in platinum forceps.

A. The flame is coloured (especially after moistening with HCl or H_2SO_4). No. 32.

B. The flame is not coloured. V., No. 43.

Examination for Bases:

The colour of the flame appears—

	Alone.	*Through Blue Glass.*	*Through Green Glass.*	
32	Violet.	Reddish-violet.	Bluish-green.	**Potassium.**
33	* Orange.	Do.	Orange-yellow.	**Potassium and Sodium.**
34	* Orange.	Invisible or faint-blue.	Do.	**Sodium.**
35	* Carmine-red.	Violet-red.	Invisible.	**Lithium.**
36	† Yellowish-green.	Bluish-green.	Green.	‡ **Barium.**
37	† Yellowish-red.	Greenish-grey.	Finch-green.	‡ **Calcium.**
38	† Carmine-red.	Purple.	Faint-yellow.	‡ **Strontium.**

39. Green; after moistening with HCl, blue. **Copper.**

* When moistened with H_2SO_4, and heated for a short time only.

† Repeatedly moistened with H_2SO_4, and strongly heated.

‡ Ba, Ca, and Sr can be detected when together by moistening with HCl, and observing the flashes of colour produced on introducing the moist assay into the flame.

Examination for Acids:

40. Yellowish-green, similar to the Ba flame. **Molybdic acid.**

40*a*. *Confirmation.* Gave with borax the reaction No. 19.

41. Yellowish-green (the salts are moistened with H_2SO_4). **Phosphoric acid.**

41*a*. *Confirmation.* On heating with Mg in closed tube, and moistening with water, PH_3 is evolved.

42. Beautiful green (the salts are moistened with H_2SO_4). **Boric acid.**

42*a*. *Confirmation.* On heating with $CaFl_2$ and $HKSO_4$ in platinum spoon, an intense green flame of boron fluoride is produced.

REMARKS.

Chlorides and nitrates also give green flashes; but the coloration is faint, and soon disappears.

The flame colours of the elements already detected, viz., As, Sb, Pb (blue), and Zn (greenish-white), are mostly obscured by the application of concentrated H_2SO_4.

V. The substance is moistened with cobalt solution, and strongly heated on charcoal.

43. Blue infusible mass. **Alumina.**

44. Blue infusible mass. **Phosphates of the earths.**

45. Blue infusible mass. **Silicates of the earths.**

43*a*. *Confirmation.* No flame coloration obtained in No. 41; and no silica-skeleton with microcosmic salt.

44*a*. *Confirmation.* A yellowish-green flame-coloration was obtained in No. 41.

45*a*. *Confirmation.* With microcosmic salt a silica-skeleton is obtained.

46. Blue glass. **Alkaline borates.**

47. Blue glass. **Alkaline phosphates.**

48. Blue glass. **Alkaline silicates.**

46*a*. *Confirmation.* A beautiful green flame-coloration is obtained in No. 42.

47*a*. *Confirmation.* A yellowish-green flame-coloration is obtained in No. 41.

48*a*. *Confirmation.* With microcosmic salt a silica-skeleton is obtained.

49. Flesh-red mass. **Magnesia.**

50. Violet mass. **Zinc Oxide.**

51. Green mass. **Oxides of Zinc, Tin, Antimony,** and **Titanium.** (Already found.)

VI. The substance is heated with Na_2CO_3 in a glass tube closed at one end.

52. Metallic sublimate, which may be collected into beads. **Mercury.**

52*a*. *Confirmation.* Heated with $Na_2S_2O_3$ in the closed tube, black HgS is obtained.

53. Odour of NH_3. **Ammonia.**

53*a*. *Confirmation.* White clouds with HCl.

DETECTION OF ACIDS.

VII. The substance is heated with $HKSO_4$ in a tube closed at one end.

a. A coloured gas is evolved. No. 54.
b. A colourless but odorous gas is evolved. No. 60.
c. A colourless and inodorous gas is evolved. No. 68.
d. No reaction is obtained. VIII., No. 71.

54. Red vapours with odour of nitrous acid. **Nitric** or **nitrous acid.**

54*a*. *Confirmation.* A strip of paper, moistened with ferrous sulphate solution, placed in the tube, turns brown.
Nitrates heated with powdered potassium cyanide on platinum foil deflagrate with explosion.

55. Yellowish-green gas, with odour of Cl. **Chloric acid.**

55*a*. *Confirmation.* The substance detonates on charcoal.

56. Violet vapours, which turn starch-paste blue. **Iodine.**

56*a*. *Confirmation.* Iodide compounds added to a microcosmic bead containing copper oxide colour the flame a pure green.

57. The preceding reaction obtained on adding ferrous sulphate. **Iodic acid.**

57*a*. *Confirmation.* The substance detonates on charcoal.

58. Reddish-brown vapours, which turn starch-paste yellow. **Bromine.**

58*a*. *Confirmation.* Bromine compounds added to a microcosmic bead containing copper oxide, colour the flame greenish-blue.

59. The same reaction. **Bromic acid.**

59*a*. *Confirmation.* The substance detonates on charcoal.

60. Vapours which give white clouds with NH_3, and have the odour of **Hydrochloric acid.**

60*a*. *Confirmation.* Chlorine compounds added to a microcosmic bead containing copper oxide, colour the flame an intense blue.

61. Pungent, corrosive gas, which attacks glass. **Hydrofluoric acid.**

62. Odour of hydrogen sulphide. **Hydrosulphuric acid.**

62*a*. *Confirmation.* Sulphides heated in an open tube held obliquely evolve SO_2 known by its odour, and its action on moist blue litmus paper.

63. Odour of burning sulphur, without separation of sulphur. **Sulphurous acid.**

64. The same reaction, with separation of sulphur. **Thiosulphuric acid.**

65. Peculiar pungent odour, brings tears into the eyes, and renders lime-water turbid. **Cyanic acid.**

66. Acetic odour. **Acetic acid.**

67. Odour of hydrocyanic acid. **Hydrocyanic acid.**

68. The gas is expelled with effervescence, and renders lime-water turbid. **Carbonic acid.**

69. The gas burns with blue flame. **Carbonic oxide.**

70. Carbonization takes place. **Organic acids.**

VIII. The substance, which forms a sulphide when heated on charcoal with Na_2CO_3, is heated with caustic potash in a platinum spoon, and the whole is thrown into water along with a clean silver coin.

71. The coin does not become brown. **Sulphuric acid.**

71*a*. *Confirmation.* To detect sulphuric acid in presence of sulphur compounds (No. 62), the substance is dissolved in water acidified with nitric acid, and the sulphuric acid is precipitated by means of $BaCl_2$.

Insoluble sulphates are first boiled with a solution of Na_2CO_3, filtered and acidified.

IX. The following acids have been already found :

72. **Phosphoric** (No. 41), **Boric** (No. 42), **Silicic** (No. 45).

II. SYSTEMATIC EXAMINATION OF COMPOUND SUBSTANCES.

After Egleston.

The substance may contain As, Sb, S, Se, Fe, Mn, Cu, Co, Ni, Pb, Bi, Ag, Au, Hg, Zn, Cd, Sn, Cl, Br, I, CO_2, SiO_2, HNO_3, H_2O, &c.

The substance is heated on charcoal in the oxidizing flame to detect volatile constituents, such as *As*, *Sb*, *S*, *Se*, *Pb*, *Bi*, *Cd*, &c. (par. 25 et seq.).

Volatile constituents absent. Divide into three parts, and go to A.	*Volatile constituents are present.* (1) Produce an incrustation, and treat this with microcosmic salt and Sn for Sb (par. 113), or separate Pb and Bi, according to pars. 111 112 and 123. *a*. Yellow incrustation. With microcosmic salt, black bead, disappearing with blue flame, giving in no part a green Sb flame. **Pb, Bi.** *b*. Yellow incrustation, usually with white border. With microcosmic salt, black or grey bead, disappearing with blue flame ; the border disappearing with green flame. **Pb, Sb.** *c*. Yellow incrustation, as in *b*, but no blue flame. **Bi, Sb.** (2) Odour of As, S, Se, or in presence of Sb ; roast a larger quantity on charcoal until the volatile constituents are removed, or the odour disappears; divide into three parts, and go to A.

A. *Treatment of the First Part.*

Dissolve a small quantity in borax on platinum wire in the O. Fl., and note the colour. When several oxides are present, successive colours often appear; in this case, saturate the bead and toss it off into a porcelain dish (par. 41). Prepare several beads in this way, and treat them on charcoal with Pb, Ag, or Au in a strong R. Fl. (pars. 133 and 136). If the mass spreads over the charcoal, continue blowing until a bead is formed.

The metallic bead is removed from the borax whilst hot, or with a hammer when cold, all fragments being carefully preserved.

The metallic bead contains the reduced Ni, Cu, Ag, Au, Sn, Pb, and Bi (Sn, Pb, and Bi are partially volatilized).

Treat the bead on charcoal in the O. Fl. until all the Pb is removed, or remove the Pb with boric acid (par. 135). Ni, Co, Ag, Au remain behind.

Treat the residue on charcoal (O. Fl.) with microcosmic salt, and remove the bead whilst hot:

A green bead when cold indicates (par. 136) **Ni** and **Cu.**
„ yellow „ „ **Ni.**
„ blue „ „ **Cu.**

The Cu bead heated on charcoal (R. Fl.) with Sn becomes red (par. 134).

The presence of Ag and Au is ascertained by special examination.

The borax retains the Fe, Mn, Co, &c.

Dissolve a fragment of the bead in borax on the platinum wire; a blue bead results. **Co.**

In presence of much iron add more borax to detect the Co (par. 132).

Dark violet or black bead in O. Fl. **Mn.**

When only Fe and Mn are present, an almost colourless bead (R. Fl.) results.

Test in the wet way (par. 67), for **Cr**, **Ti**, **Mo**, **Nb**, **W**, **V.**

B. *Treatment of the Second Part.*

Heat on charcoal in R. Fl. with Na_2CO_3, and look for indications of **Zn**, **Cd**, and **Sn**. If a white incrustation results, treat with cobalt solution (par. 61).

C. *Treatment of the Third Part.*

Dissolve in microcosmic salt on platinum wire (O. Fl.) for **SiO_2**, and test for **Mn** with KNO_3 (par. 158).

Special Tests.

1. To confirm **As** heat on charcoal with Na_2CO_3, or in closed tube with *dry* Na_2CO_3 (par. 117 et seq.).

2. Dissolve in microcosmic salt on platinum wire in the oxidizing flame (provided the assay is neither a metal nor contains S), and test for **Sb** on charcoal with Sn in R. Fl. (par. 113).

3. Test for **Se** on charcoal (par. 167).

4. In absence of Se fuse with Na_2CO_3 (R. Fl.) and test for **S** on silver foil (par. 172). If **Se** be present, test for **S** in an open tube (par. 14). To distinguish between sulphides and sulphates see par. 173.

5. Test for **Hg** by heating in closed tube with *dry* Na_2CO_3 (No. 33 of the table at the end of the book).

6. Fuse with assay-lead and borax-glass on charcoal in R. Fl. Cupel the Pb bead for **Ag** (par. 171). Test for **Au** by means of HNO_3 (par. 142).

7. Test for **Cl**, **Br**, and **I** by microcosmic bead containing Cu (pars. 126, 128, and 143).

8. Test for **Cl** and **Br** with $HKSO_4$ (pars. 64 and 65).

9. Test for water in closed tube (par. 9).

10. Apply flame-coloration tests (par. 42).

11. Test for **CO_2** with HCl.

12. Test for **HNO_3** by means of $HKSO_4$ (par. 164).

13. Test for **Te** according to par. 174.

CONDENSED VIEW OF THE BLOWPIPE REACTIONS.

Arranged according to the Phenomena observed.

Experiment.	Observation and Inference.

(1) In Glass Matrass.	*Water is given off:* water of crystallization; alkaline reaction = NH_3; acid reaction = volatile acids.
	Gas is evolved: O, SO_2, H_2S, NO_2, CO_2, CO, CN, NH_3, HF, I, Br.
	Sublimate is formed: white = NH_4Cl, Hg_2Cl_2, $HgCl_2$, Sb_2O_3, As_2O_3, TeO_2;
	greyish-black = As, Hg, Te;
	coloured: *hot*, yellowish-brown, *cold*, yellow = S;
	hot, black, *cold*, reddish-brown = antimony sulphide;
	hot, brownish-red, *cold*, reddish-yellow = arsenic sulphide;
	black, on rubbing red = cinnabar;
	reddish-black (dark-red powder) = Se.
	Change of colour: white, yellow, white = ZnO;
	white, yellow, brown, light-yellow = SnO_2;
	white, brownish-red, yellow = PbO;
	white, orange, pale-yellow, Bi_2O_3;
	red, black, red (volatile) = HgO;
	red, black, red (non-volatile) = Fe_2O_3.
	Substance melts: alkaline salts.
	Carbonization takes place: organic bodies.
	Substance becomes phosphorescent: alkaline earths, earths, ZnO, SnO_2.
	On heating with sodium carbonate, ammonia is evolved: ammoniacal salts and organic nitrogen compounds.

BLOWPIPE REACTIONS—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.
(2) In the Open Tube.	*Odour emitted:* of SO_2 = sulphur and sulphides ; of rotten horse-radish = selenium and selenides (steel-grey sublimate with red border).
	Sublimate is formed: white and crystalline = As ; metallic globules = Hg ; white fumes, sublimate partially volatile = Sb ; white fumes, sublimate fusible to colourless drops = Te ;
(3) Alone on Charcoal.	*Substance is fusible:* (a) non-metallic bodies = alkaline and some alkaline-earthy salts ; (b) metals : readily fusible = Sb, Pb, Cd, Te, Bi, Zn, Sn ; difficultly fusible = Cu, Au, Ag.
	Substance is infusible: (a) non-metallic bodies = salts of the earths and alkaline earths, SiO_2; (b) metals = Fe, Co, Ni, Mo, Pt, Ir, Rh, Os, W.
	Substance detonates: nitrates, chlorates, bromates, and iodates.
	Substance intumesces: substances containing water, borates, alum.
	Odour emitted: S, As, Se, Te.
	Flame-coloration: yellow = Na ; yellowish-red = Ca ; red = Li, Sr ; green = Ba, B_2O_3, P_2O_5, MoO_3, Cu ; blue = $CuCl_2$, Se, As, Pb ; violet = K.

BLOWPIPE REACTIONS—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.
(3) Alone on Charcoal. *Continued.*	*Metal-reduction and incrustation :* (1) *Metal reduced without incrustation.* Shining bead = Ag, Au, Cu ; Grey powder = Fe, Co, Ni, Mo, W, Pt, Pd. (2) *Metal reduced with incrustation.* Incrustation, bluish-white and volatile = Sb ; ,, *hot* orange, *cold* lemon-yellow = Bi ; ,, *hot* lemon-yellow, *cold* sulphur-yellow = Pb ; ,, *hot* yellowish, *cold* white = Sn ; ,, dark-red = Ag. (3) *Incrustation without reduced metal.* Incrustation, white and volatile = As ; ,, *hot* yellow, *cold* white = Zn ; ,, reddish-brown, with variegated border = Cd ; ,, steel-grey = Se ; ,, white with red border = Te ; ,, *hot* yellow, *cold* white ; by blowing upon, first blue, then dark red = Mo. (In oxidizing flame only.)

BLOWPIPE REACTIONS—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.				
(4) On Charcoal with Sodium Carbonate.	*Sodium sulphide formed:* sulphates and sulphides. *Metal-reduction and incrustation* as in No. 3.				
	Colour of Bead.	*Oxidizing Flame.*		*Reducing Flame.*	
		Hot.	Cold.	Hot.	Cold.
(5) On Platinum Wire with Borax.	Yellow (non-saturated bead)	Fe, U, Ce, Cr, Mo.	...	Ti, Mo.	Ti.
	Yellow (saturated bead)	V, Ti, W, Pb, Bi, Sb, Zn, Cd.	Fe, U, Ce.	W.	...
	Red (non-saturated bead)	...	...	...	Cu (brownish).
	Red (saturated bead)	Fe, Ce, U, Cr, Mo.	...	...	Cu (brownish).
	Brown	...	Ni.	(s.b.), Mo, V, Ti.	(s.b.), W, Mo, Ti.
	Violet	Mn, Ni.	Mn.	...	...
	Blue	Co.	Co, Cu.	Co.	Co.
	Green	Cu.	Cr, V.	Fe, U, Cr.	Fe, V, U, Cr.

BLOWPIPE REACTIONS—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.				
	Colour of Bead.	*Oxidizing Flame.*		*Reducing Flame.*	
		Hot.	Cold.	Hot.	Cold.
(6) On Platinum Wire with Microcosmic Salt.	Yellow (non-saturated bead)	Fe, U, V, Ce, Ag.	V, Ni.	Ti, Fe.	Ni.
	Yellow (saturated bead)	U, V, W, Ti, Ag, Pb, Bi, Sb, Zn, Cd.	V, Ni.	Ti.	Ni.
	Red (non-saturated bead)	Ni, Cr.	...	Cr.	Cu.
	Red (saturated bead)	Fe, Ce, Ni, Cr.	Fe (brownish)	Fe, Cr, Ni.	Cu.
	Brown	...	...	V.	...
	Violet	Mn.	Mn.	...	Ti.
	Blue	Co.	Co, Cu.	Co.	Co, W.
	Green	Cu, Mo.	U, Cr, Mo.	U, Cu, Mo, W.	U, Mo, Cr, V.
	Silica Skeleton = SiO_2.				
(7) Heated on Platinum Wire, after Moistening with HCl.	*The flame is coloured:* Yellow = Na; through blue glass invisible to blue; through green glass, orange. Yellowish-red = Ca; reaction obscured by Ba; through blue glass, greenish-grey; green glass, siskin-green. Red = Li; obscured by Na; through blue glass, violet; green glass, invisible. Red = Sr; obscured by Ba; through blue glass, violet-red; green glass, momentarily yellowish. Green = B_2O_3, P_2O_5, Ba (through green glass, bluish-green), MoO_3, Tl. Blue = Cu (subsequently green), In, Se, As, Pb, Sb. Violet = K, obscured by Na; through blue glass, purple-red; green glass, bluish-green.				

BLOWPIPE REACTIONS—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.
(8) On Platinum Foil with Sodium Carbonate and Nitre.	Yellow mass = Cr. Green ,, = Mn.
(9) On Charcoal with Cobalt Solution.	Blue infusible mass = Al_2O_3, SiO_2, and earthy phosphates and silicates. Blue glass = alkaline phosphates, borates, and silicates. Green mass = ZnO, TiO_2, SnO_2, Sb_2O_3. Flesh-coloured mass = MgO. Brown mass = BaO. Grey mass = BeO, CaO, SrO. Violet mass = ZrO_2.
(10) With $Na_2S_2O_3$ in a tube closed at one end.	White = ZnO. Red = Sb_2O_3, CdO (*hot ; cold*, yellow). Yellow = As_2O_3, CdO. Brown = SnO_2. Green = Cr_2O_3, MnO. Black = PbO, Fe_2O_3, CoO, CuO, NiO, UO_3, Bi_2O_3, Ag_2O, HgO, Sb_2O_3 (at first red sulphide also).
(11) With H_2SO_4, or $HKSO_4$ in Glass Matrass.	*Coloured vapours :* brown = N_2O_3 ; yellowish-green, ClO_2 ; violet = I ; reddish-brown = Br. *Odorous gases :* SO_2, HCl, HF, H_2S. *Colourless and inodorous gases :* CO_2, CO.

BLOWPIPE REACTIONS—*Continued.*

EXPERIMENT.	OBSERVATION AND INFERENCE.
(12) With iodine sulphide (*a*) on gypsum slab ;	*Yellow film :* Pb, Ag, and in minute quantities, many metals.
	Yellow and *scarlet :* Hg.
	Orange-red : Sb, As.
	Brownish-yellow : Sn.
	Reddish-brown : Se.
	Purplish-brown : Te.
	Chocolate-brown : Bi (red edge).
	Greenish-brown : Co (green edge).
	Deep ultramarine blue : Mo.
	Faint greenish-blue : W.
(*b*) on charcoal.	*White :* Cu, Cd, Zn.
(13) With Zn and HCl after previous decomposition.	Solution is coloured blue, green, blackish-brown = MoO_3. blue, copper-red = WO_3. blue, green, violet = V_2O_5. green = CrO_3. violet = TiO_2.

TABULAR VIEW

OF THE BEHAVIOUR OF THE ALKALIS, EARTHS, AND METALLIC OXIDES, ALONE AND WITH REAGENTS, BEFORE THE BLOWPIPE.

[*Mainly from Plattner's Blowpipe Analysis.*]

ALKALIS.	*Alone on Platinum Wire.*	*Alone on Platinum Foil.*	*Remarks.*
1. **Potash.**	When fused under the point of the blue flame, colours the outer flame violet. A very small amount of soda obscures the reaction (see par. 50).		In solution, turn red litmus paper blue.
2. **Soda.**	When fused under the point of the blue flame, colours the outer flame strongly reddish-yellow. The presence of potash, even in considerable quantity, does not interfere with the reaction.		
3. **Lithia.**	When fused under the point of the blue flame, colours the outer flame carmine-red. A very considerable quantity of potash, even when in excess of the lithium, does not interfere with the reaction. A small quantity of soda, however, alters the reaction, and the flame is more or less yellowish-red to reddish-yellow (see par. 52).	When melted, turns the foil around the melted alkali dark yellow. The discoloration disappears when the foil is washed and ignited, but the platinum has lost its brightness, and acquired a dull appearance, which is especially seen when the foil is heated to redness.	
4. **Ammonia.**	The nitrate, sulphate, and chloride colour the outer flame pale-green.		Easily recognized by its characteristic odour; turns red litmus paper blue.

EARTHS.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*On Charcoal with Sodium Carbonate.*	*With Cobalt Solution in the Ox. Flame.*
5. Baryta.	The hydrate fuses, boils, and swells up, becomes fixed on the surface, and lastly sinks into the charcoal with violent ebullition. The carbonate readily melts to a clear glass, which, on cooling, is enamel-white; on repeated fusion it boils, spirts about, becomes caustic, and is absorbed. In the forceps it colours the outer flame yellowish-green. (See par. 53.)	The carbonate dissolves with effervescence to a clear glass; added in a certain amount the bead becomes enamel-white on flaming; in larger quantity it becomes enamel-white of itself on cooling.	As with borax.	Fuses with the flux, and is absorbed by the charcoal.	Fuses to a brownish-red bead, which, on cooling, loses colour, and in the air soon falls to a light-grey powder. If the solution be very dilute the bead becomes pale-brown only.
6. Strontia.	The hydrate behaves like baryta. The carbonate fuses only on the edges, and swells up with a cauliflower-like appearance. The ramifications are luminous and tinge the reducing flame red, and, on cooling, exhibit an alkaline reaction. In the forceps colours the outer flame purple-red. (See par. 55.)	Like baryta.	Like baryta.	The oxide is insoluble. The carbonate, mixed with an equal volume of the flux, melts to a clear glass, which becomes milk-white on cooling. Heated more strongly the glass boils, and the alkali becomes caustic, and sinks into the charcoal. If more carbonate be added it does not fuse, but becomes caustic, and sinks into the charcoal.	Sinters and assumes a black or dark-grey colour.

EARTHS.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*On Charcoal with Sodium Carbonate.*	*With Cobalt Solution in the Ox. Flame.*
7. Lime.	The oxide fuses and remains unaltered. The carbonate becomes caustic and whiter in colour, strongly luminous in the flame, alkaline in reaction, and falls to powder when moistened with water. In the forceps it colours the outer flame feebly red. (See par. 54.)	Readily dissolves to a clear glass, which becomes opaque on flaming. The carbonate dissolves with effervescence. Added in larger quantity gives a clear glass, which, on cooling, becomes opaque and crystalline, but is never so milk-white as with baryta or strontia.	Dissolves in large quantity (the carbonate with effervescence) to a clear glass, which, when moderately saturated, becomes opaque on flaming. When fully saturated, the clear glass becomes milk-white on cooling.	Insoluble. The flux sinks into the charcoal, leaving the lime behind.	Is perfectly infusible, and becomes grey.
8. Magnesia.	The carbonate is decomposed, becomes luminous in the flame, and acquires an alkaline reaction.	Like lime, but not so distinctly crystalline.	Dissolves readily (the carbonate with effervescence) to a clear glass, which becomes opaque on flaming; on complete saturation becomes milk-white of itself on cooling.	Like lime.	On long blowing acquires a pale flesh-tint, only seen properly when quite cold. The phosphate and arsenate fuse and assume a violet-red colour.
9. Alumina.	Unaltered.	Dissolves slowly to a clear glass, which does not become opaque either on flaming or on cooling after full saturation. When added in fine powder and in large quantity an opaque glass is formed, which has a crystalline surface on cooling, and is scarcely fusible.	Dissolves slowly to a clear glass that always remains clear. When added in excess the undissolved portion becomes semi-transparent.	Swells up a little, forms an infusible compound, and the excess of flux sinks into the charcoal.	After strong blowing assumes a beautiful blue colour, which is only properly seen on cooling.

EARTHS.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*On Charcoal with Sodium Carbonate.*	*With Cobalt Solution in the Ox. Flame.*
10. Beryllia.	Unaltered.	In large amount dissolves to a clear glass, which becomes milk-white on flaming or on cooling after full saturation.	As with borax.	Insoluble.	Assumes a pale bluish-grey colour.
11. Yttria.	Unaltered.	Like beryllia.	Like beryllia.	Insoluble.	
12. Erbia.	Assumes in the reducing flame a lighter colour, and becomes translucent.	Dissolves somewhat slowly to a clear glass, which becomes milk-white on flaming or on cooling after full saturation.	As with borax.	Insoluble.	
13. Zirconia.	Infusible. On strong ignition emits an exceedingly dazzling light.	Like beryllia.	Dissolves somewhat less readily than in borax, and yields more easily an opaque glass.	Insoluble.	Assumes a dirty violet colour.

EARTHS.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*On Charcoal with Sodium Carbonate.*	*With Cobalt Solution in the Ox. Flame.*
14. **Thoria.**	Unaltered.	In small quantity dissolves to a clear glass; when saturated becomes milk-white on cooling; but when the glass remains clear on cooling flaming will not render it opaque.	As with Borax.	Insoluble.	
15. **Silica.**	Unaltered.	Dissolves slowly to a clear, difficulty fusible glass, which does not become opaque on flaming.	In very small quantity dissolves to a clear glass. In other cases the undissolved portion floats about as a semi-transparent mass (the silica skeleton) in the clear glass. The reaction should be observed in the hot bead, and with a lens if necessary.	Dissolves with strong effervescence to a clear glass.	With a little solution assumes a pale-bluish colour, which, on addition of more solution, becomes black or dark-grey. The thin edges of the assay can be fused by strong ignition to a reddish-blue glass.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
16. Antimony Trioxide.	*Ox. Flame.* Is driven from where first placed, and partly collects about another spot. *Red. Flame.* Is reduced and volatilized, the charcoal around being incrusted principally with trioxide; the outer flame is tinged greenish-blue.	*Ox. Flame.* Dissolves in large amount to a clear glass, which is yellowish whilst hot, and colourless when cold. On charcoal the dissolved oxide can be driven off, so that the addition of tin then produces no further change. *Red. Flame.* The glass, which has been treated for a short time only in the oxidizing flame, becomes greyish and clouded on charcoal from separation of particles of metallic antimony; these, however, volatilize on longer blowing, and the glass becomes clear. With tin the glass becomes grey or black according to its degree of saturation.	*Ox. Flame.* Dissolves with ebullition to a clear glass, which, when hot, is only slightly coloured yellow. *Red. Flame.* On charcoal the saturated glass is first clouded, but afterwards clear, the reduced antimony being volatilized. Treated with tin the glass is grey on cooling from reduced antimony, but by longer blowing is again clear. When the glass contains but little dissolved oxide, tin produces a grey cloudiness.	On charcoal in the *Ox.* and *Red. Flames* is easily reduced, but the metal vaporizes at once, and deposits a white incrustation of oxide.	*a. With Cobalt Solution:* the charcoal incrustation moistened with cobalt solution, and ignited in the Ox. Flame partially volatilizes, but the remaining portion is left as higher oxide, and, when quite cold, appears of a dirty bluish-green colour. *b. With Sodium Hyposulphite:* first red then black sulphide. *c. Iodide Film:* orange-red.
17. Arsenic Trioxide.	Volatilizes readily below a red heat.			Reduced on charcoal with evolution of arsenic vapour, readily recognized by its strong odour of garlic.	*a. With Sodium Hyposulphite:* yellow melt. *b. Iodide Film:* buff.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodinm Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES:				
18. Bismuth Trioxide.	*Ox. Flame.* On platinum foil readily fuses to a dark-brown mass, which is pale-yellow when cold. On charcoal in *Ox. & Red. Flames* reduced to metal, which, on continued blowing, gradually volatilizes, incrusting the charcoal with yellow oxide. Beyond this incrustation is a thin white one of carbonate. In the reducing flame these incrustations disappear without colouring the flame.	*Ox. Flame.* Dissolves readily to a clear yellow glass; when small in amount the cold bead is colourless; with a larger amount the glass is yellowish-red when hot, yellow during cooling, and when quite cold opalescent. *Red. Flame.* On charcoal the glass is at first grey and clouded; then the oxide is reduced to metal with effervescence, and the glass becomes again clear. The bismuth separates more quickly on addition of tin.	*Ox. Flame.* Dissolves readily to a clear yellow glass, which is colourless when cold. When in large quantity the glass becomes enamelled on flaming, and in still larger quantity the glass of itself becomes enamel-white on cooling. *Red. Flame.* On charcoal, especially with tin, the glass becomes clear and colourless when hot, but on cooling is blackish-grey and opaque. The bead is thus coloured even by very small quantities of oxide.	On charcoal it is immediately reduced to metallic bismuth.	*a. With Sodium Hyposulphite:* black sulphide. *b. Iodide Film:* chocolate brown, sometimes fringed with red near the assay.
19. Cadmium Oxide.	*Ox. Flame.* Unaltered on platinum foil.	*Ox. Flame.* Dissolves in large amount to a clear yellow glass, the colour almost disappearing on cooling. When strongly saturated the glass becomes milk-white on flaming, and in still larger amount the glass of itself becomes enamel-white on cooling.	*Ox. Flame.* Dissolves in very large amount to a clear glass, which, on considerable addition, is yellowish when hot and colourless when cold, and when saturated becomes milk-white on cooling.	*Ox. Flame.* Insoluble.	*a. With Sodium Hyposulphite:* hot, cinnabar red, cold, yellow melt, passing through all shades from red to yellow during cooling.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
19. Cadmium Oxide. *Continued.*)	*Red. Flame.* On charcoal quickly disappears, and incrusts the surrounding charcoal with a reddish-brown to dark-yellow powder, the colour being only properly seen when cold. The charcoal around the incrustation exhibits a variegated coloration.	*Red. Flame.* On charcoal the glass containing the oxide boils, the cadmium is reduced, and the metal at once volatilizes and produces a dark-yellow incrustation of oxide.	*Red. Flame.* On charcoal the dissolved oxide is slowly and incompletely reduced. The reduced metal yields a slight incrustation of dark-yellow oxide, the colour being only properly seen when cold. Addition of tin accelerates the reduction.	*Red. Flame.* On charcoal is immediately reduced; the metal volatilizes and incrusts the charcoal with reddish-brown to dark-yellow oxide. Further away the charcoal is variously coloured.	
20. Cerium Sesquioxide.	In the *Ox. Flame* is converted into cerium dioxide.	*Ox. Flame,* Dissolves to a yellow to red glass, similar to that of iron sesquioxide; on cooling the bead is yellow. At a certain degree of saturation the bead becomes enamelled on flaming, and with more becomes so of itself on cooling. *Red. Flame.* The glass, when yellow coloured, becomes colourless. When strongly saturated it becomes enamel-white and crystalline on cooling.	*Ox. Flame.* As with borax, but that the colour disappears entirely on cooling. *Red. Flame.* The glass, both hot and cold, is quite colourless, thus being distinguished from the iron glass. It does not become opaque at any degree of saturation.	Insoluble. The flux sinks into the charcoal.	

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
21. Chromium Sesquioxide.	*Ox. & Red. Flames.* Remains unaltered.	*Ox. Flame.* Dissolves slowly, but colours strongly. Added in small quantity the glass is yellow when hot (trioxide), and yellowish-green when cold; in larger amount the bead is dark-red when hot, yellow during cooling, and when quite cold a fine yellowish-green. *Red. Flame.* The slightly saturated bead is a fine green, both hot and cold (sesquioxide). With more it becomes darker, or of a pure emerald-green. Tin produces no change.	*Ox. Flame.* Dissolves to a clear glass, which is reddish whilst hot, dirty-green during cooling, and when quite cold has a fine green colour. *Red. Flame.* As in the Ox. Flame, but that the colours are somewhat darker; the same with tin.	*Ox. Flame.* On platinum wire dissolves to a dark brownish-yellowglass, which, on cooling, is yellow and opaque (trioxide). *Red. Flame.* The glass is opaque, and when cold is green (sesquioxide). Cannot be reduced to metal on charcoal, but remains after the flux has sunk into the charcoal, as the green sesquioxide.	*With Sodium Hyposulphite:* green melt.
22. Cobalt Monoxide.	*Ox. Flame.* Unaltered. *Red. Flame.* Shrinks somewhat, and is reduced without fusion to metal; this is magnetic, and assumes a metallic lustre under the burnisher.	*Ox. Flame.* Colours very strongly. The glass, both hot and cold, is a pure smalt-blue. When strongly saturated the colour is so deep that the glass appears black. *Red. Flame.* As in the Ox. Flame.	*Ox. Flame.* As with borax, but that the colour is proportionately less intense, as is best seen on cooling. *Red. Flame.* As in Ox. Flame.	*Ox. Flame.* On platinum wire, in very small quantity, dissolves to a transparent pale-red mass, becoming grey on cooling. *Red. Flame.* On charcoal is reduced to a grey magnetic powder, which assumes a metallic lustre under the burnisher.	*a. With Sodium Hyposulphite:* black melt. *b. Iodide Film:* greenish-brown, with green margin, the brown colour passes to green after some time.

METALLIC OXIDES. *Alphabetically arranged.*	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
	IN OXIDIZING AND REDUCING FLAMES.				
23. Copper Oxide.	*Ox. Flame.* Fuses to a black globule which soon spreads out, and is reduced on the under side. *Red. Flame.* The oxide is reduced at a temperature below that at which copper melts; the reduced portions are luminous with a copper lustre, but when the blast is interrupted, these oxidize on the surface, becoming brown or black. On strong ignition, fuses to a bead of metallic copper.	*Ox. Flame.* Colours somewhat strongly. In small quantity the glass is green whilst hot and blue when cold. In larger quantity it is dark-green to opaque whilst hot and greenish-blue when cold. *Red. Flame.* With a certain saturation the glass becomes quite colourless, but on cooling, is red, and becomes opaque (suboxide). On charcoal metallic copper separates out, and the glass, when cold, is quite colourless. When a glass containing the oxide is heated with tin on charcoal it becomes brownish-red and opaque on cooling (suboxide).	*Ox. Flame.* Is proportionately not so strongly coloured as is borax. The colours, according as a smaller or larger quantity is added, are, as with borax, hot, green to dark-green and opaque; on cooling blue to greenish-blue. *Red. Flame.* When somewhat strongly saturated the glass is dark-green, and, on cooling, becomes at the moment of solidification dark-red and opaque (suboxide). If the glass, containing but little oxide, be treated on charcoal with tin it is colourless when hot, and on cooling also becomes red to brownish-red and opaque.	*Ox. Flame.* On platinum wire dissolves to a clear green glass, which, on cooling, loses its colour, and becomes opaque. *Red. Flame.* On charcoal is readily reduced to metal, which, by sufficient heat, can be fused to one or more buttons.	*a. With Sodium Hyposulphite:* black mass. *b. Iodide Film on Charcoal:* white.
24. Didymium Oxide.	Unaltered.	*Ox. Flame.* Dissolves to a clear colourless glass. *Red. Flame.* When strongly saturated the bead has a pale-rose colour.	*Ox. Flame.* As with borax. *Red. Flame.* When saturated, and after long blowing, the bead is violet by transmitted light.	Insoluble. The flux is absorbed by the charcoal.	

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
25. Germanium Oxide.	*Ox. Flame.* The oxide is unchanged even at a white heat. *Red. Flame.* Reducible with difficulty to the metallic state, with formation of a white oxide film on the charcoal. A fragment of metal heated on charcoal fuses to a glistening bead which moves about emitting white fumes when removed from the flame, and also forms a white incrustation.—*C. Winkler.*	Dissolves to a colourless bead which remains unchanged in the red. flame.—*Ziessler.*	Dissolves with some little difficulty to a colourless bead. Addition of tin produces no change.—*Ziessler.*		*a. Ge* heated on platinum foil melts and forms a brittle and fusible alloy with the platinum.—*C. Winkler.* *b. With Cobalt Solution:* no reaction. *c. With Potassium Iodide and Sulphur:* no reaction.—*Ziessler.*
26. Gold Tri-Oxide.	*Ox. & Red. Flames.* Is reduced, at a red heat, to metal, which easily fuses to a button.	*Ox. & Red. Flames.* Is reduced without dissolving, and on charcoal can be fused to a metallic globule.	As with borax.	As with borax; the flux sinks into the charcoal.	
27. Indium Oxide.	*Ox. Flame.* Dark-yellow whilst hot, but lighter coloured again on cooling. Does not melt. *Red. Flame.* Is gradually reduced, the metal volatilizing and incrusting the charcoal. A very distinct bluish-violet colour is imparted to the outer flame.	*Ox. Flame.* Dissolves to a clear glass, which, when hot, is faint yellowish, and on cooling colourless, in large quantity however becoming clouded. *Red. Flame.* The glass is unaltered. On charcoal the oxide is reduced; the metal reoxidizing and incrusting the charcoal. The bluish-violet coloration of the outer flame is perceptible in spite of the soda reaction	As with borax. The glass heated with tin on charcoal becomes grey and cloudy.	*Ox. Flame.* Insoluble. *Red. Flame.* On charcoal is reduced. The metal partially volatilizes and incrusts the charcoal with oxide, and in part remains as almost silver-white globules amongst the fused salt.	
28. Iridium Oxide.	Is reduced at a red heat, but the metallic particles cannot be melted.	*Ox. & Red. Flames.* Is reduced without dissolving, but even on charcoal the metal cannot be collected to a button.	As with borax.	As with borax; the flux sinks into the charcoal.	

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
29. Iron Sesquioxide.	*Ox. Flame.* Unaltered. *Red. Flame.* Becomes black and magnetic (ferroso-ferric oxide).	*Ox. Flame.* In small amount the glass is yellow when hot, and colourless when cold; in larger quantity the hot glass is red, and becomes yellow when cold; in still larger amount the hot glass is dark-red and the cold glass dark-yellow. *Red. Flame.* The glass becomes bottle-green (ferroso-ferric oxide). On charcoal with tin it is at first bottle-green, but on longer blowing vitriol-green (monoxide).	*Ox. Flame.* With a certain amount the hot glass is yellowish-red, and on cooling becomes first yellow, then greenish, and finally colourless. In very large quantity the glass is dark-red whilst hot, on cooling becomes first brown-red and then dirty-green, and when cold has a yellow colour. The colours disappear much sooner on cooling than with borax. *Red. Flame.* When in small quantity the glass, containing sesquioxide, appears unchanged; in larger amount it is red when hot, and on cooling is first yellow, then greenish, and finally brownish tinted. Treated on charcoal with tin the glass on cooling becomes green and finally colourless (monoxide).	*Ox. Flame.* Insoluble. *Red. Flame.* On charcoal is reduced, yielding a grey magnetic metallic powder when the particles of charcoal are washed away.	*With Sodium Hyposulphite:* black mass.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
30. Lanthanum Oxide.	Unaltered.	*Ox. Flame.* Dissolves to a clear colourless glass, which, with a certain degree of saturation, becomes enamel-white, and when more strongly saturated becomes of itself enamelled on cooling. (*Berzelius.*) *Red. Flame.* As in the Ox. Flame.	As with borax.	Insoluble. The flux sinks into the charcoal, and the grey-coloured oxide remains behind. (*Berzelius.*)	
31. Lead Oxide.	Minium heated on platinum foil blackens, and at incipient redness changes to the yellow oxide; heated more strongly this fuses to a yellow glass. On charcoal in the *Ox.* and *Red. Flames* it is immediately converted with effervescence into metal, which on continued blowing, gradually volatilizes, yielding an incrustation of yellow oxide: beyond this is a thinner white incrustation of carbonate. These disappear in the Red. Flame, colouring the flame azure blue.	*Ox. Flame.* Readily dissolves to a clear yellow glass, which is colourless when cold; added in larger quantity the glass becomes opaque on flaming, and in still larger amount becomes opaque and enamel-yellow of itself on cooling. *Red. Flame.* The glass spreads out on charcoal and becomes clouded; on continued blowing the lead oxide is reduced to metal with effervescence, and the glass is again clear.	*Ox. Flame.* As with borax. But a larger addition of oxide is necessary to tinge the hot glass yellow. *Red. Flame.* The glass becomes grey and clouded on charcoal. On larger addition of oxide the charcoal is incrusted yellow. In presence of tin the glass is of a darker grey colour and more clouded, but is never quite opaque.	*Ox. Flame.* On platinum wire dissolves easily to a clear glass, which, on cooling, becomes opaque and yellowish. *Red. Flame.* On charcoal is immediately reduced to metal, which, on continued blowing, yields an incrustation of oxide.	*a. With Sodium Hyposulphite:* black melt. *b. Iodide Film:* chrome yellow.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
32. Manganese Sesquioxide.	*Ox. & Red. Flames.* Infusible. The sesquioxide and the peroxide when heated to a sufficiently high temperature lose oxygen, being converted into a brownish-red mass of Mn_3O_4.	*Ox. Flame.* Colours very strongly. The hot glass is violet (amethystine) when hot and violet-red on cooling. Added somewhat in excess the glass becomes quite black and opaque, the colour being seen only when the soft glass is flattened between the forceps. *Red. Flame.* The coloured glass becomes colourless (monoxide). When very strongly coloured the reduction is better effected on charcoal with addition of tin than on the platinum wire.	*Ox. Flame.* A considerable addition is requisite to colour the glass, which is brownish-violet when hot and reddish-violet when cold, but is never opaque. When the glass contains so little oxide as to be colourless, the colour is brought out by adding nitre (see par. 157). The glass containing the oxide boils and gives off gas at a high temperature. *Red. Flame.* The coloured glass becomes almost colourless (monoxide), and then undergoes no further change.	*Ox. Flame.* On platinum wire or foil dissolves in very small quantity, forming a clear transparent green glass, which is bluish-green and opaque when cold (sodium manganate). *Red. Flame.* Cannot be reduced to metal on charcoal; the flux sinks into the charcoal and the monoxide remains behind.	*With Sodium Hyposulphite:* green melt.
33. Mercury Oxide.	Immediately reduced and volatilized.			Heated in glass matrass (or alone) decomposes; the metallic mercury sublimes and condenses in the neck of the glass as a metallic mirror consisting of minute particles, which, on careful tapping, unite to distinct globules.	*a. With Sodium Hyposulphite:* black sulphide. *b. Iodide Film:* yellow and scarlet red.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
34. Molybdenum Trioxide.	*Ox. Flame.* Fuses, spreads out, volatilizes and forms at a certain distance a yellowish pulverulent incrustation, which, nearest to the assay, consists of small crystals. On cooling the powder becomes white, and the crystals colourless. Interior to this is a thin non-volatile film of dioxide, which has a metallic dark copper-red colour when cold. (Par. 39.) The white incrustation becomes deep-blue (molybdic molybdate) on contact with the reducing flame. *Red. Flame.* The greatest part sinks into the charcoal, and at a high temperature is reduced to metal, which can be obtained as a grey powder, on washing away the particles of charcoal.	*Ox. Flame.* Dissolves readily and in considerable quantity to a clear glass, which is yellow whilst hot, and colourless on cooling. In very large quantity the glass is dark-yellow to dark-red whilst hot, and when cold is opaline to bluish-grey enamel. *Red. Flame.* The glass from the Ox. Flame becomes, on stronger saturation, brown, and, when still more strongly saturated, opaque (dioxide). When strongly heated the dioxide separates, in the form of black flakes, which are easily seen in the yellowish glass when this is flattened in the forceps.	*Ox. Flame.* Dissolves readily to a clear glass, which, on moderate addition, is yellowish-green when hot, and almost colourless when cold. On charcoal the glass becomes quite dark, and on cooling is a beautiful green (from the dioxide produced by the reducing action of carbon monoxide). *Red. Flame.* The glass produced in the Ox. Flame becomes a very dark dirty-green, but is a purer green on cooling. A similar reaction on charcoal. With tin the green colour is somewhat deepened (monoxide?).	*Ox. Flame.* On platinum wire fuses with effervescence to a clear glass, which becomes milk-white on cooling. *Red. Flame.* On charcoal first fuses with effervescence, and then the molten mass is absorbed by the charcoal, and is for the most part reduced to metal, which, after washing, is obtained as a steel-grey powder.	*a. With Sodium Hyposulphite:* brown mass. *b. Iodide Film:* deep ultramarine blue. *c.* Molybdenum compounds, heated in a capsule with concentrated sulphuric acid, give a deep-blue liquid on the addition of alcohol, or when breathed upon.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
35. Nickel Monoxide.	*Ox. Flame.* Unaltered. *Red. Flame.* On charcoal is reduced to a coherent metallic powder, which cannot be fused; it is decidedly magnetic, and under the burnisher it attains a metallic lustre.	*Ox. Flame.* Colours somewhat intensely. In small amount the hot glass is violet, and when cold a pale reddish-brown. On larger addition the colours are darker. *Red. Flame.* The glass becomes grey and clouded or quite opaque from separation of finely divided metal. On continued blowing the particles of metal collect together without fusing, and the glass becomes colourless. On charcoal, and especially after the addition of tin, the reduction proceeds more quickly, and the reduced nickel unites with the tin to a button.	*Ox. Flame.* Dissolves to a reddish glass, which is yellow on cooling. In larger quantity the hot glass is brownish-red, and becomes reddish-yellow on cooling. *Red. Flame.* On platinum wire the glass remains unchanged. Treated on charcoal with tin it is at first grey and opaque, but on longer blowing all the nickel is reduced, and the glass becomes colourless.	*Ox. Flame.* Insoluble. *Red. Flame.* On charcoal is easily reduced to white shining metallic particles, which, after washing away adherent charcoal, are found to be strongly magnetic.	*With Sodium Hyposulphite:* black sulphide.
36. Niobium Pentoxide.	*Ox. & Red. Flames.* On heating assumes a yellowish tint, but is white again on cooling. No further alteration takes place.	*Ox. Flame.* Dissolves readily to a clear colourless glass, which at a certain degree of saturation becomes opaque on flaming, and on a larger addition becomes of itself opaque on cooling.	*Ox. Flame.* Dissolves in large quantity to a clear glass, which is yellow whilst hot and colourless on cooling.	*Ox. Flame.* With an equal volume of sodium carbonate fuses with effervescence; with a larger amount sinks into the charcoal.	*With Cobalt Solution:* acquires a brownish-grey colour.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
36. Niobium Pentoxide. (*Continued.*)		*Red. Flame.* A glass which in the Ox. Flame would become opaque on cooling, remains clear in the Red. Flame.	*Red. Flame.* Added in large quantity the glass becomes brown.	*Red. Flame.* As in Ox. Flame, cannot be reduced to metal.	
37. Osmium Dioxide.	*Ox. Flame.* Changed into the tetroxide, and this volatilizes, without yielding any incrustation, as a penetrating and suffocating vapour which has a very irritating action on the eyes. *Red. Flame.* Reduced to a dark-brown infusible metallic powder, which very readily oxidizes to the tetroxide.			Very easily reduced to an infusible metallic powder, which can be obtained pure by washing.	
38. Palladium Monoxide.	Is reduced at a red heat, but the particles of metal cannot be fused.	*Ox. & Red. Flames.* Is reduced without dissolving. The separated metal cannot be united to a button even on charcoal.	As with borax.	Insoluble. The flux sinks into the charcoal, and metallic palladium is left behind as an infusible powder.	
39. Platinum Dioxide.	Is reduced at a red heat, but the particles of metal cannot be fused.	*Ox. & Red. Flames.* Is reduced without dissolving. The particles of metal cannot be united to a button even on charcoal.	As with borax.	As with borax; the flux sinks into the charcoal.	

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
40. Rhodium Oxide. **41. Ruthenium Oxide.**	Are readily reduced, but the particles of metal cannot be fused.	*Ox. & Red. Flames.* Are reduced without dissolving. The metallic particles cannot be fused to a button even on charcoal.	As with borax.	As with borax; the flux sinks into the charcoal.	
42. Silver Oxide.	Readily reduced to metal, which fuses to one or more metallic globules.	*Ox. Flame.* Partially dissolved and partially reduced to metal. On cooling the glass is opalescent or milk-white according to the amount dissolved. Metallic silver fused with borax in a clay capsule gives a similar glass. *Red. Flame.* On charcoal the glass becomes at first greyish from particles of reduced silver, but afterwards all the silver becomes reduced and collects to a button, and the glass is clear and colourless.	*Ox. Flame.* The oxide and also the metal impart a yellowish colour to the glass. When containing much oxide the cold glass is opalescent, and by daylight yellowish, whilst by gaslight it is reddish coloured. *Red. Flame.* As with borax.	At once reduced to globules of metal, the flux sinking into the charcoal.	*a. With Sodium Hyposulphite:* black. *b. Iodide Film:* hot, light yellow; cold, faint greyish yellow.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
43. Tantalum Pentoxide.	*Ox. & Red. Flames.* On heating acquires a slight yellowish tint, but becomes white again on cooling, no further change taking place.	*Ox. & Red. Flame.* Dissolves readily to a clear glass, which, at a certain point of saturation, is yellowish whilst hot and colourless on cooling, and can be rendered opaque by flaming. On a larger addition the glass of itself becomes enamel-white on cooling.	*Ox. Flame.* Dissolves in large amount to a clear glass; when in very large quantity the glass is yellowish whilst hot, but becomes colourless when cold. *Red. Flame.* The glass produced in the Ox. Flame undergoes no change.	*Ox. Flame.* With somewhat more than an equal volume of flux melts with effervescence on charcoal to a bead, which, however, soon spreads out; with a somewhat larger addition of sodium carbonate sinks into the charcoal. *Red. Flame.* The same. A reduction to metal cannot be effected.	*With Cobalt Solution:* after long ignition appears light-grey, but on cooling has a slight red colour, like that of magnesia. When not quite free from alkali it sinters and becomes bluish-black.
44. Tellurium Dioxide.	*Ox. Flame.* Fuses and is reduced with effervescence. The metal immediately volatilizes, and yields a white incrustation of the dioxide, which has usually a red or dark-yellow border. *Red. Flame.* The same; the outer flame is coloured bluish-green.	*Ox. Flame.* Dissolves to a clear colourless glass, which on charcoal becomes grey from particles of reduced metal. *Red. Flame.* A glass obtained on platinum wire in the Ox. Flame becomes on charcoal first grey, but is again colourless after all the tellurium is reduced and volatilized. The charcoal becomes incrusted with dioxide.	As with borax.	On platinum wire dissolves to a clear colourless glass, which becomes white on cooling. On charcoal it is reduced and volatilized, an incrustation of dioxide being thus formed.	*Iodide Film:* purplish-brown.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
45. Thallium Monoxide.	Melts, and is immediately reduced with effervescence to metallic globules, which volatilize on continued blowing, and yield a slight white incrustation.	*Ox. Flame.* Dissolves readily to a colourless glass. When the cooled bead is heated to below redness the surface is coloured brown; if the heat be raised to redness the bead becomes again colourless after slight blowing. *Red. Flame.* The glass acquires a greyish turbidity, which disappears on continued blowing.	*Ox. Flame.* Dissolves to a clear glass, which when slightly blown upon becomes turbid. *Red. Flame.* On charcoal the yellow glass becomes grey and clouded.	On charcoal is reduced to metal with evolution of vapour and formation of a white incrustation.	*a. Flame Coloration:* grass green. *b. Sodium Hyposulphite:* black melt. *c. Iodide Film:* a series of colours—first orange, followed by yellow, white, light blue, green and black.
46. Tin Dioxide.	*Ox. Flame.* The monoxide burns like tinder, and passes into dioxide. This is strongly luminous in the flame, and is yellowish whilst hot, and a dirty yellowish-white on cooling.	*Ox. Flame.* Dissolves very slowly and in slight amount to a clear colourless glass, which remains clear on cooling, and is not rendered opaque by flaming. A saturated and quite cold bead, when heated to dull redness becomes opaque, loses its spherical shape, and is indistinctly crystalline.	*Ox. Flame.* Dissolves in small amount and very slowly to a clear colourless glass, which remains clear on cooling.	*Ox. Flame.* On platinum wire combines with effervescence with the flux forming a swollen infusible mass.	*a. With Cobalt Solution:* assumes a bluish-green colour, which can only be properly seen when quite cold. *b. With Sodium Hyposulphite:* brown sulphide.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
46. Tin Dioxide. (*Continued.*)	*Red. Flame.* On strong and continued ignition is reduced to metal, a slight incrustation of dioxide being generally formed near to the assay.	*Red. Flame.* A non-saturated glass undergoes no alteration. Cn charcoal some tin can be reduced from a glass containing much oxide.	*Red. Flame.* The glass remains unaltered both on platinum wire and on charcoal.	*Red. Flame.* On charcoal is reduced to metal.	*c. Iodide Film:* brownish-yellow.
47. Titanium Dioxide.	*Ox. & Red. Flames.* Assumes a yellowish colour whilst hot, but is white again on cooling, no further change taking place.	*Ox. Flame.* Dissolves readily to a clear glass, which, when much is present, is yellow whilst hot and colourless on cooling, and on flaming becomes opaque. When in very large quantity the glass becomes of itself enamel-white on cooling. *Red. Flame.* On small addition the glass is yellow; in larger quantity dark-yellow to brown (sesquioxide). A saturated glass becomes enamel-blue on flaming.	*Ox. Flame.* Dissolves readily to a clear glass, which, when much is present, is yellow when hot and becomes colourless on cooling. *Red. Flame.* The glass from the Ox. Flame remains yellow whilst hot, but reddens on cooling, and at last attains a beautiful violet colour (sesquioxide). If the dioxide is not free from iron the glass becomes brownish-yellow to brownish-red on cooling. Treated with tin on charcoal the glass becomes violet if it does not contain too much iron.	*Ox. Flame.* Dissolves on charcoal with effervescence to a dark-yellow glass, which on cooling down to below dull redness crystallizes. When quite cold the glass is greyish-white to white. *Red. Flame.* The same. A reduction to metal cannot be effected.	*With Cobalt Solution:* assumes a yellowish-green colour similar to, but not so fine as, that produced with zinc oxide.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
48. Tungsten Trioxide.	*Ox. Flame.* Unaltered unless the temperature is so high that from formation of carbon monoxide a reduction to tungsten dioxide takes place. *Red. Flame.* Becomes black from formation of dioxide, but does not fuse.	*Ox. Flame.* Dissolves readily to a clear colourless bead. On a moderately large addition the glass is yellow whilst hot; on a larger addition it becomes enamel-like on flaming, and on a still larger addition it becomes of itself enamel-white on cooling. *Red. Flame.* When added in certain quantity the glass remains unaltered; on a larger addition it is yellow to dark-yellow, and yellowish-brown on cooling (dioxide). On charcoal these reactions are obtained with a smaller quantity of substance. When not too strongly saturated the addition of tin produces darker colours.	*Ox. Flame.* Dissolves readily to a clear colourless glass, which, when strongly saturated is yellow whilst hot. *Red. Flame.* The bead shortly becomes dirty-green whilst hot, and on cooling blue (W_2O_5); on longer blowing it is bluish-green on cooling. On charcoal, especially with tin, it becomes dark-green (dioxide). If the oxide contains iron the hot glass appears yellow on the platinum wire, and on cooling is brownish-red (blood-red) as with titanium dioxide. The glass containing iron, treated on charcoal with tin, becomes blue if the amount of iron be inconsiderable.	*Ox. Flame.* On platinum wire dissolves to a clear dark-yellow glass, which, on cooling, becomes crystalline and opaque, and is white or yellowish coloured. *Red. Flame.* On charcoal a large quantity of oxide can be reduced to metal with but little sodium carbonate. With more flux the whole sinks into the charcoal, and sodium tungstite is formed, which has a yellow colour and a metallic lustre.	*Iodide Film:* faint greenish-blue, close to the assay.

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
49. Uranium Trioxide.	*Ox. Flame.* Is infusible, but assumes a dirty dark yellowish-green colour (U_3O_8). *Red. Flame.* Becomes black, and shows this colour also on rubbing in the mortar (U_2O_5).	*Ox. Flame.* Behaves like iron sesquioxide, but for equal quantities the colours are somewhat lighter. The strongly saturated glass becomes enamel-yellow on flaming. *Red. Flame.* Gives colours like those produced by iron sesquioxide. The green glass (U_3O_8) up to a certain point of saturation turns black on flaming, but it becomes neither enamel-like nor crystalline. Treated with tin on charcoal the glass becomes dark-green.	*Ox. Flame.* Dissolves to a clear yellow glass, becoming yellowish-green on cooling. *Red. Flame.* The glass becomes dirty-green, but on cooling has a pure and fine green colour (U_3O_8). Treated on charcoal with tin the green colour becomes darker.	*Ox. Flame.* Insoluble. With a small addition of flux gives indication of fusing. With more carbonate the mass becomes yellowish-brown. With still more flux the oxide sinks into the charcoal. *Red. Flame.* The same. The oxide cannot be reduced to metal.	*With Sodium Hyposulphite:* black
50. Vanadium Pentoxide.	Fuses. The portion in contact with the charcoal is reduced and sinks into the charcoal; the upper portion assumes the colour and lustre of graphite, and consists of trioxide.	*Ox. Flame.* Dissolves to a clear glass. When small in amount the glass is colourless, but with more is yellow when hot and greenish yellow on cooling. *Red. Flame.* The glass becomes brownish whilst hot, and on cooling a beautiful chrome-green.	*Ox. Flame.* Dissolves to a clear glass, which, when not too little is added, is dark-yellow whilst hot and light-yellow on cooling. *Red. Flame.* As with borax.	Fuses together with the flux and sinks into the charcoal.	

METALLIC OXIDES.	*Alone on Charcoal and in the Forceps.*	*With Borax on Platinum Wire.*	*With Microcosmic Salt on Platinum Wire.*	*With Sodium Carbonate.*	*Other Reactions.*
Alphabetically arranged.	IN OXIDIZING AND REDUCING FLAMES.				
51. Zinc Oxide.	*Ox. Flame.* Becomes yellow whilst hot, and white again on cooling. Is infusible, but becomes strongly luminous in flame. *Red. Flame.* Disappears gradually, being reduced to metal, which immediately volatilizes and re-oxidizes; the greater part of the volatilized zinc is deposited as oxide on another part of the charcoal, forming a distinct incrustation, which is at first yellowish, but becomes white on cooling.	*Ox. Flame.* Dissolves readily and in large quantity to a clear glass, which is yellowish whilst hot and colourless when cold. On a larger addition it becomes enamel-like on flaming; and on still larger addition becomes enamel-like of itself on cooling. *Red. Flame.* The saturated glass is at first opaque and grey (a portion of the oxide separating out on incomplete fusion), but on longer blowing becomes clear. On charcoal the oxide is gradually reduced, but the metal is at once volatilized and re-oxidized, and an incrustation deposited.	As with borax.	*Ox. Flame.* Insoluble. *Red. Flame.* Is reduced on charcoal. The metal volatilizes, is re-oxidized, and forms an incrustation of oxide on the charcoal. On strong ignition a zinc-flame may even be produced.	*a. With Cobalt Solution:* assumes a beautiful yellowish-green colour, which is best seen when quite cold. *b. With Sodium Hyposulphite:* white. *c. Iodide Film on Charcoal:* white.

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